Shape grammar implementations
The last ~~35~~ 36 years

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Architecture, Design & Media Technology
Aalborg University

Shape grammar implementation: from theory to useable software
Design Computing and Cognition workshop, Stuttgart, 11 July 2010

Outline

- Overview & issues
- Early history
- Examples
  - Categorised by issue

Today’s presentations

- Li, Chau, Chen, Wang
- *A prototype system for developing two- and three-dimensional shape grammars*

- Trescak, Esteva, Rodriguez
- *Shape grammar interpreter for rectilinear forms*

- Hoisl, Shea
- *A 3D spatial grammar interpreter applet*

- Jowers, Earl
- *QI – a shape grammar interpreter for curved shapes*

- Ertelt, Shea
- *Shape grammar implementation for machining planning*

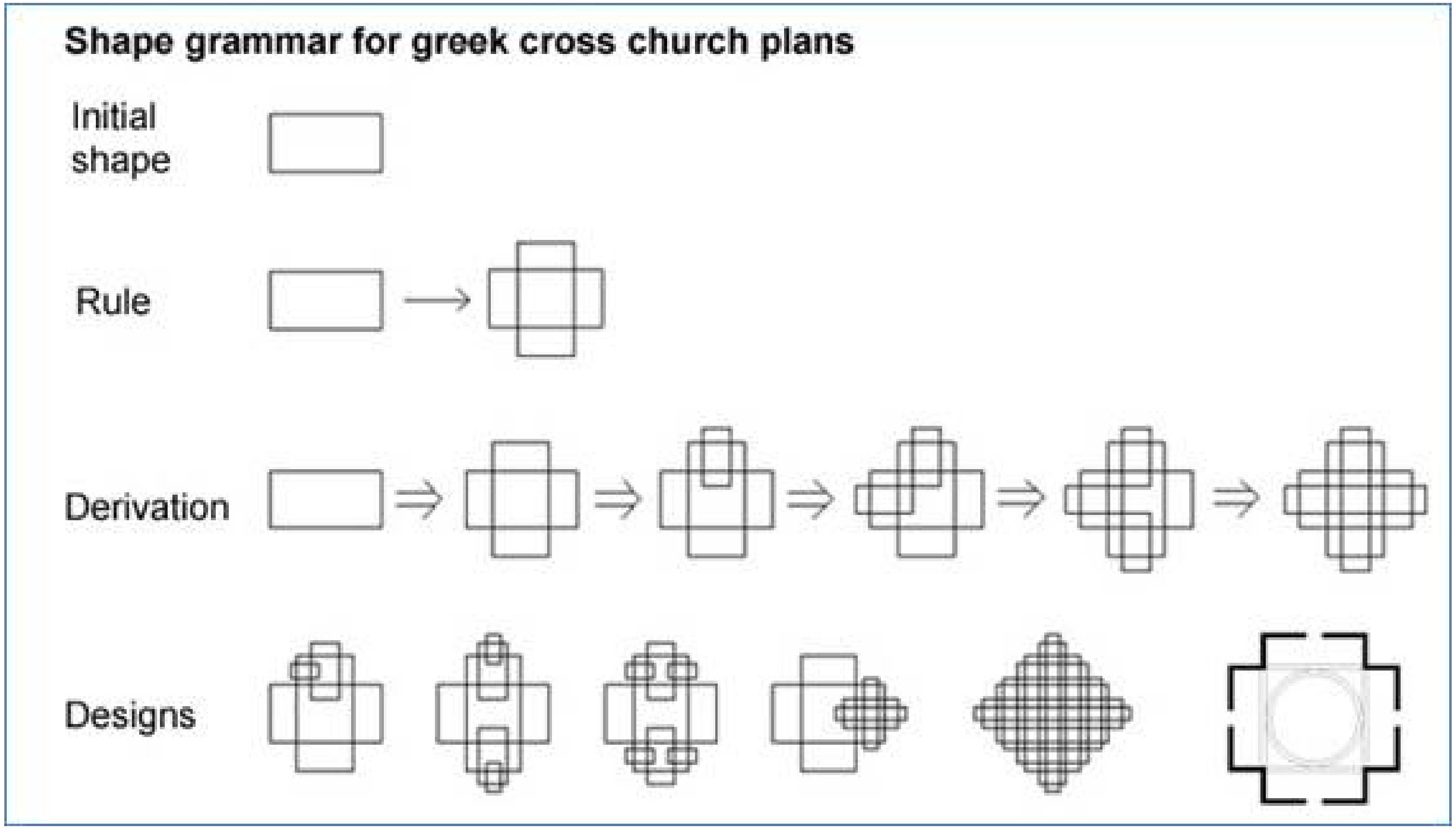
- Jowers, McKay
- *Shape grammar implementation with vision*

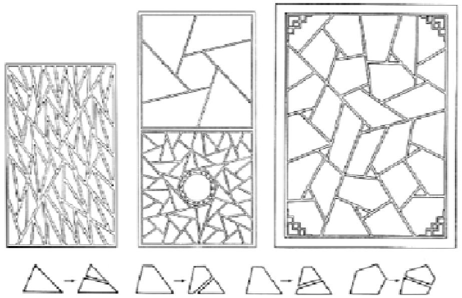
- Correia, Duarte, Leitão
- *MALAG: a discursive grammar interpreter for the online generation of mass customized housing*

Challenge

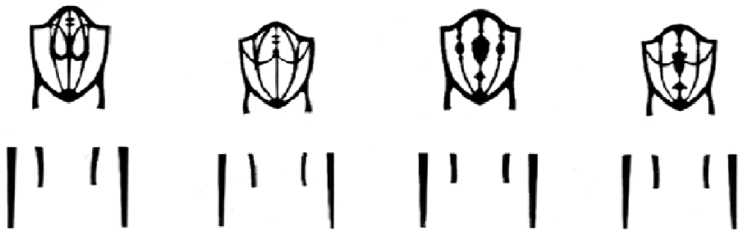
We want conceptual design tools that *support* designers' ways of thinking and working and enhance creativity, e.g. offering design alternatives difficult or not possible without the use of such tools.

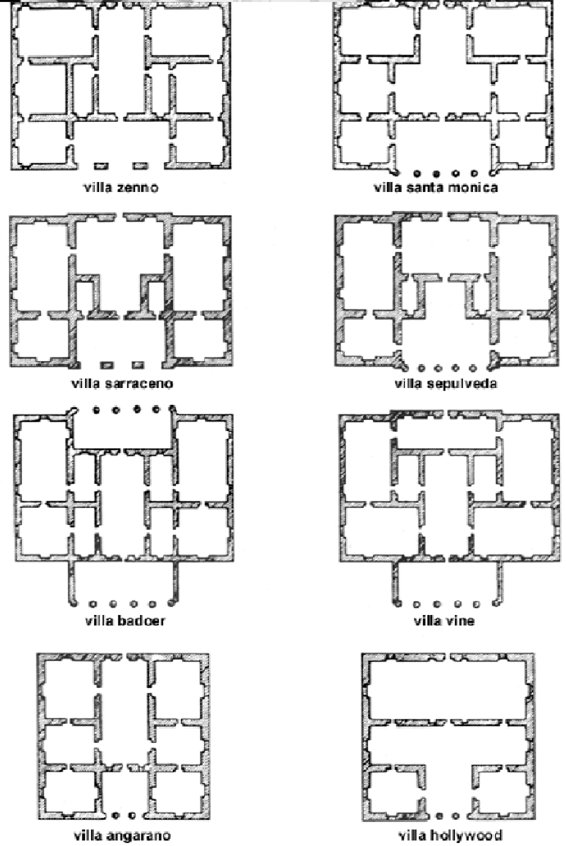
Shape grammars

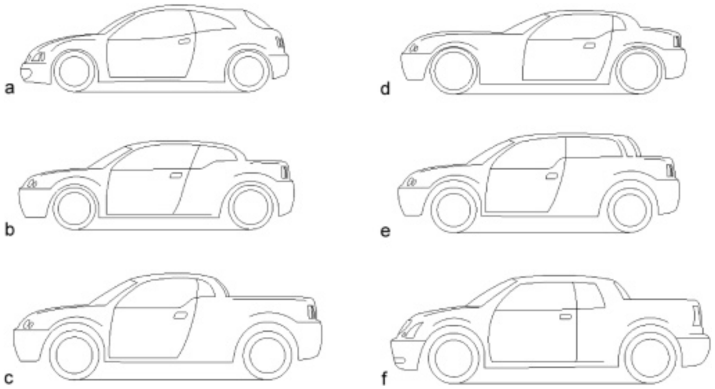


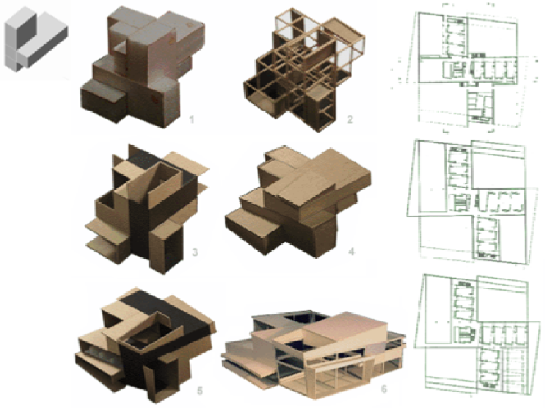


Asurface

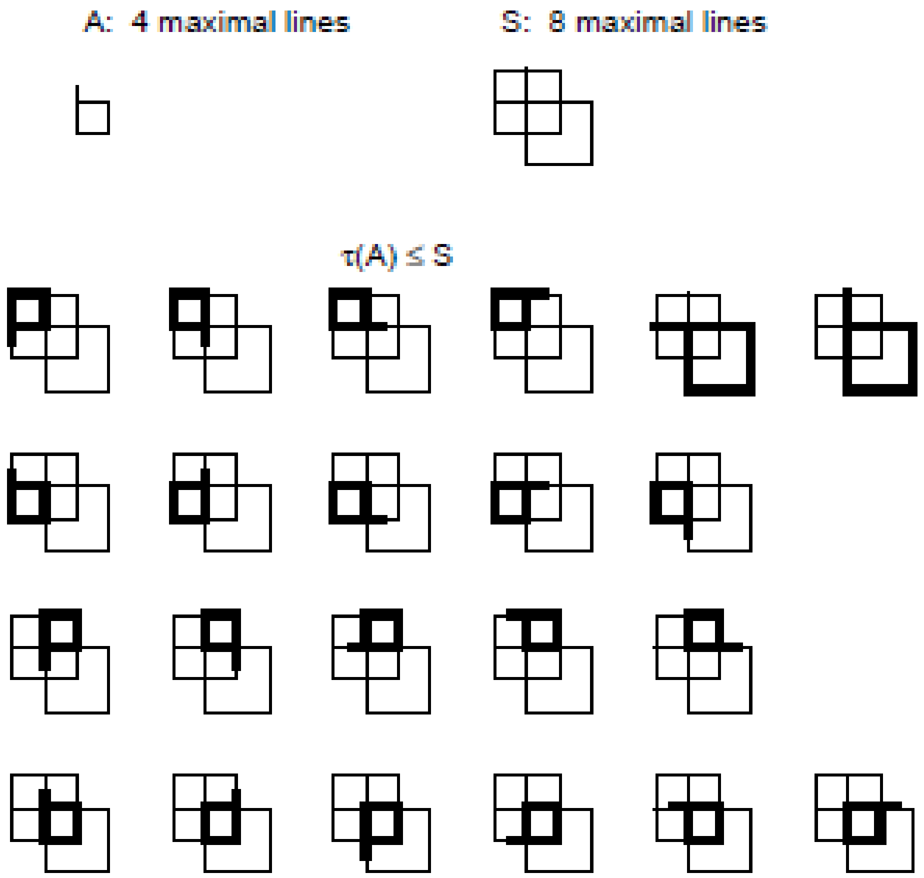



villa zenno
villa santa monica
villa sarraceno
villa sepulveda
villa badoer
villa vine
villa angarano
villa hollywood


a
d
b
e
c
f



Emergence



A: 4 maximal lines

S: 8 maximal lines

τ(A) ≤ S

Conceptual design tool requirements
DCC 2010 workshop notes

- Ease of use
- Modeling capabilities
- Visualization capabilities
- Multiplicity
- Flexibility
- Simultaneity
- Environment
- Semantics
- Entity identity vs. emergence
- Entity linkages
- Abstract objects
- Diagram support
- History and Design Space exploration
- (Re)generativity

SG implementation research

- Representations & algorithms
  - geometry, other design attributes, control
- User interaction/interface
- Specific design problems
- Integration into design process

Issues

Gips 1999

1. Interface
2. Parametric grammars
3. Subshape problem
4. Curved elements
5. Representations
6. Extensions to SG
7. ‘Proof of concept’ vs. production software
8. The ‘big enchilada’ or ‘one piece at a time’

http://www.shapegrammar.org/implement.pdf

Idealised general SG implementation

Chau et. al (2004)

1. Subshape recognition and emergence
2. Shape recognition under Euclidean transformations
3. Parametric shape rules
4. Shape recognition for parametric grammars
5. 3D shapes
6. Curvilinear basic elements
7. Intuitive user interface
8. Aesthetic measures for ranking & selecting designs
9. Surfaces and solids
10. Unambiguous interpretation of designs to physical realisation

Chau H H, Chen X, McKay A, de Pennington A, 2004, "Evaluation of a 3D shape grammar implementation" in *Design Computing and Cognition '04: Proceedings of the First International Conference on Design Computing and Cognition* Ed J S Gero (Kluwer, Dordrecht) 357-376

SG system tasks

Gips 1999

1. Generation (design)
2. Parsing (analysis)
3. Inference (grammar construction)
4. CAD program for SG development (designer’s aid)

History of implementations

- Early work (1970s & 80s)
  - Primarily general interpreters
- Middle period (1990s & early 2000s)
  - Broader work includes systems for specific design problems
  - Work includes systems that don’t support emergence
- Past decade: broad mix
  - General interpreters
  - Specific implementation issues
  - Specific design problems

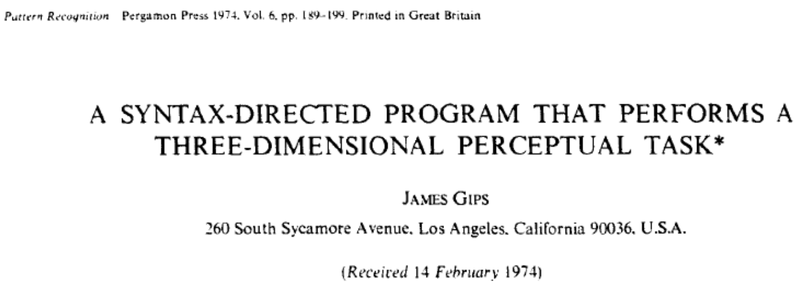
Implementations

Chau et. al 2004

	Name	Reference	Tool(s) used	Shape emergence	2D/3D
1	Simple interpreter	Gips 1975	SAIL[1]	No	2D
2	Shepard-Metzler analysis	Gips 1974	SAIL[1]	No	2D/3D
3	Shape grammar interpreter	Krishnamurti 1982	Conventional language	Yes	2D
4	Shape generation system	Krishnamurti and Giraud 1986	PROLOG[2]	Yes	2D
5	Queen Anne houses	Flemming 1987	PROLOG	No	2D
6	Shape grammar system	Chase 1989	PROLOG	Yes	2D
7	Genesis (CMU)	Heisserman 1991	C/CLP(R)[3]	No	3D
8	GRAIL	Krishnamurti 1992		Yes	2D
9	Grammatica	Carlson 1993		No	
10		Stouffs 1994		Yes	2D/3D
11	Genesis (Boeing)	Heisserman 1994	C++/CLP(R)[3]	No	2D/3D
12	GEdit[5]	Tapia 1996	LISP[4]	Yes	2D
13	Shape grammar editor	Shelden 1996	AutoLISP	Yes	2D
14	Implementation of basic grammar	Simondetti 1997	AutoLISP	No	3D
15	Shape grammar interpreter	Piazzalunga and Fitzhorn 1998	ACIS Scheme	No	3D
16	SG-Clips	Chien et al 1998	CLIPS	No	2D/3D
17	3D Shaper	Wang 1998	Java/Open Inventor	No	3D
18	Coffee maker grammar[6]	Michalek 1998	Java	No	2D/3D
19	MEMS grammar	Agarwal et al 2000	LISP		2D
20	Shaper 2D[7]	McGill 2001	Java	No	2D
21	U_{13} shape grammar implementation	Chau 2002	Perl	Yes	3D

Shephard-Metzler analysis

Gips 1974



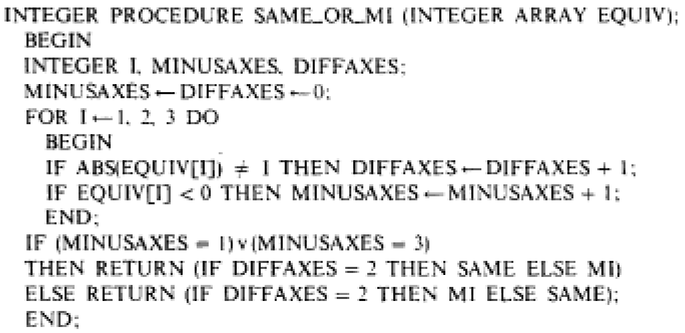
Pattern Recognition Pergamon Press 1974. Vol. 6, pp. 189–199. Printed in Great Britain

A SYNTAX-DIRECTED PROGRAM THAT PERFORMS A THREE-DIMENSIONAL PERCEPTUAL TASK*

JAMES GIPS

260 South Sycamore Avenue, Los Angeles, California 90036, U.S.A.

(*Received* 14 *February* 1974)



```
INTEGER PROCEDURE SAME_OR_MI (INTEGER ARRAY EQUIV);
  BEGIN
  INTEGER I, MINUSAXES, DIFFAXES;
  MINUSAXES ← DIFFAXES ← 0;
  FOR I ← 1, 2, 3 DO
    BEGIN
    IF ABS(EQUIV[I]) ≠ I THEN DIFFAXES ← DIFFAXES + 1;
    IF EQUIV[I] < 0 THEN MINUSAXES ← MINUSAXES + 1;
    END;
  IF (MINUSAXES = 1) ∨ (MINUSAXES = 3)
  THEN RETURN (IF DIFFAXES = 2 THEN SAME ELSE MI)
  ELSE RETURN (IF DIFFAXES = 2 THEN MI ELSE SAME);
  END;
```

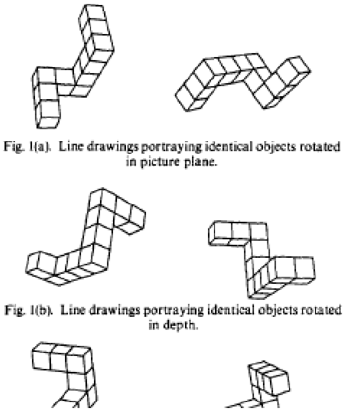


Fig. 1(a). Line drawings portraying identical objects rotated in picture plane.

Fig. 1(b). Line drawings portraying identical objects rotated in depth.

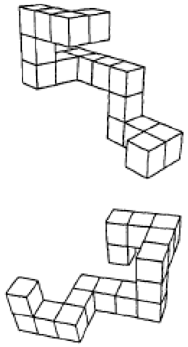


Fig. 2. A pair of more complicated line dra cessfully analyzed and compared by the prc

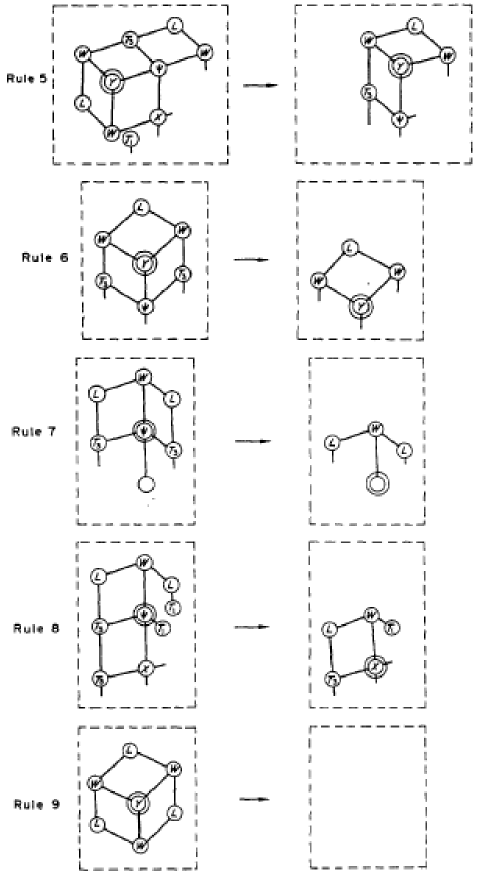
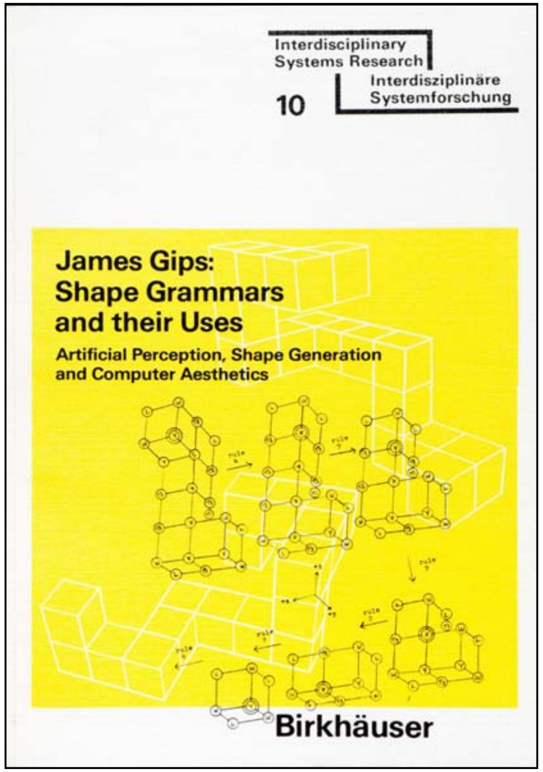
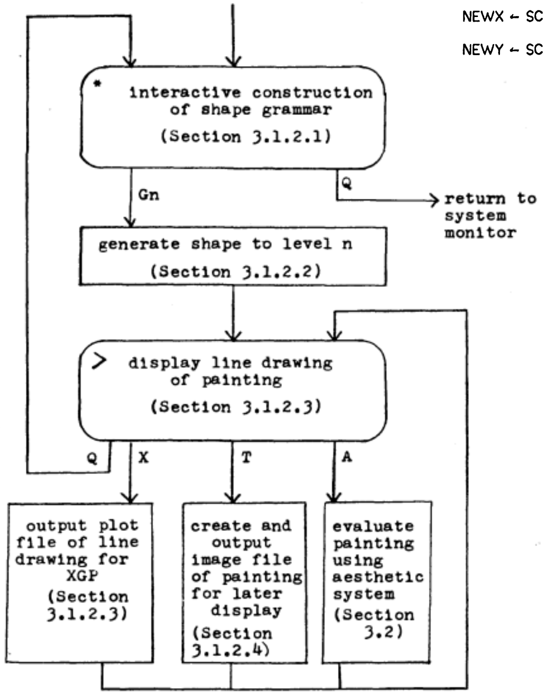


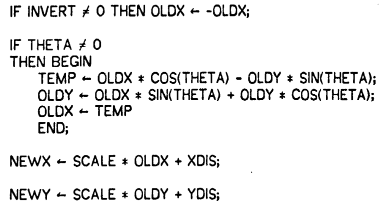
Fig. 7. Cont.

Simple interpreter

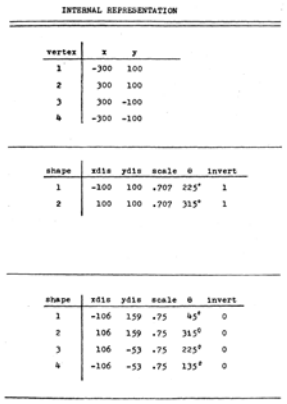
Gips 1975


Interdisciplinary Systems Research
Interdisziplinäre Systemforschung
10
James Gips:
Shape Grammars and their Uses
Artificial Perception, Shape Generation and Computer Aesthetics
Birkhäuser


* interactive construction of shape grammar (Section 3.1.2.1)
Gn
Q
return to system monitor
generate shape to level n (Section 3.1.2.2)
> display line drawing of painting (Section 3.1.2.3)
Q
X
T
A
output plot file of line drawing for XGP (Section 3.1.2.3)
create and output image file of painting for later display (Section 3.1.2.4)
evaluate painting using aesthetic system (Section 3.2)



```
IF INVERT ≠ 0 THEN OLDX ← -OLDX;

IF THETA ≠ 0
THEN BEGIN
    TEMP ← OLDX * COS(THETA) - OLDY * SIN(THETA);
    OLDY ← OLDX * SIN(THETA) + OLDY * COS(THETA);
    OLDX ← TEMP
    END;

NEWX ← SCALE * OLDX + XDIS;

NEWY ← SCALE * OLDY + YDIS;
```



INTERNAL REPRESENTATION

vertex	x	y
1	-300	100
2	300	100
3	300	-100
4	-300	-100

shape	xdis	ydis	scale	θ	invert
1	-100	100	.707	225°	1
2	100	100	.707	315°	1

shape	xdis	ydis	scale	θ	invert
1	-106	159	.75	45°	0
2	106	159	.75	315°	0
3	106	-53	.75	225°	0
4	-106	-53	.75	135°	0

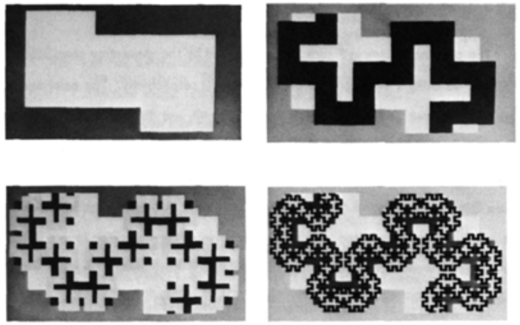


Figure 39a. Urform. Colors are black, blue, red, light blue, and white (darkest to lightest) in the final painting.

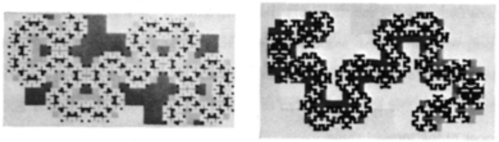


Figure 39b. Variations.

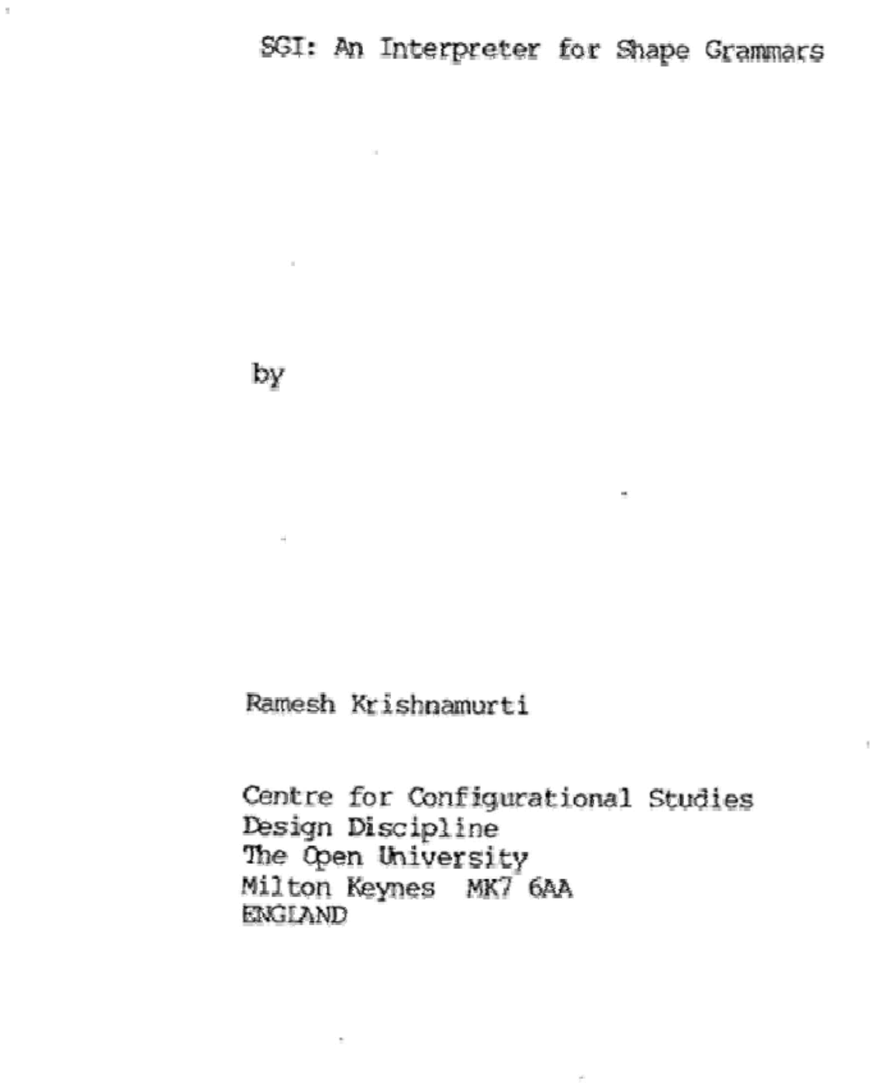
Figure 39. Urform and variations. Computer display.

SGI

Krishnamurti 1982

1. Who has referenced Krishnamurti's 1982 report in their papers?

2. Who has actually seen the report?



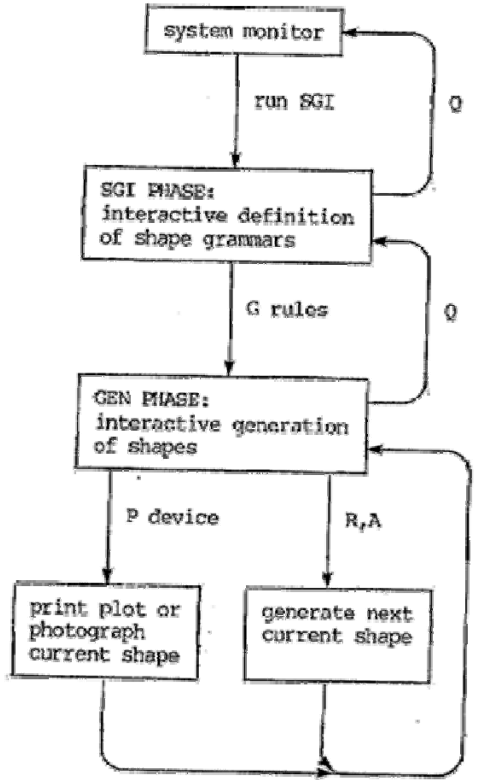
SGI: An Interpreter for Shape Grammars

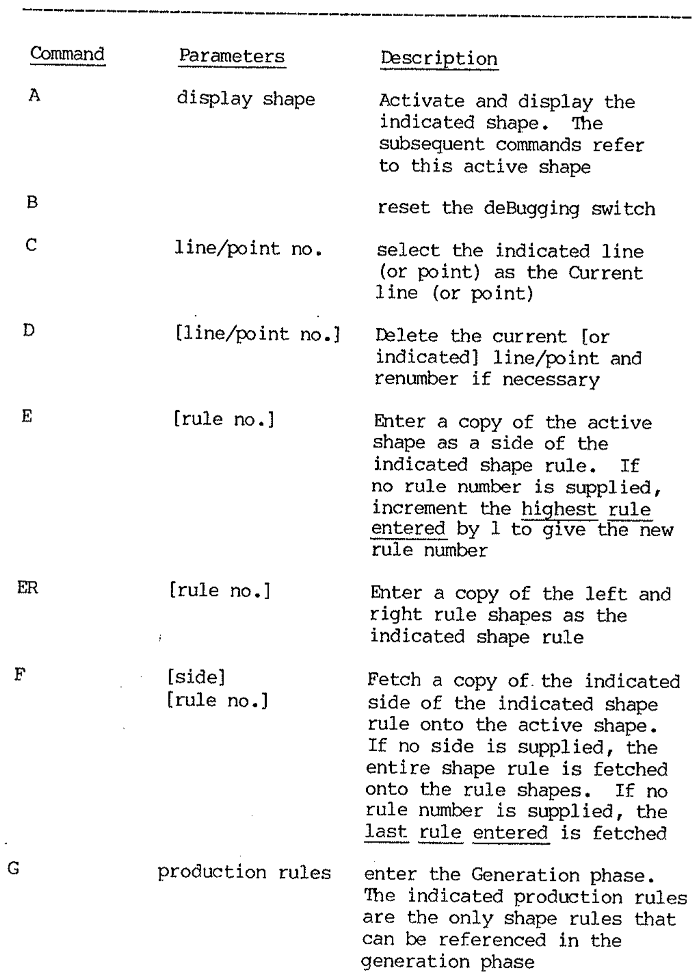
by

Ramesh Krishnamurti

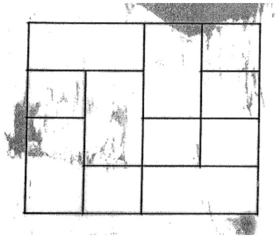
Centre for Configurational Studies
Design Discipline
The Open University
Milton Keynes MK7 6AA
ENGLAND

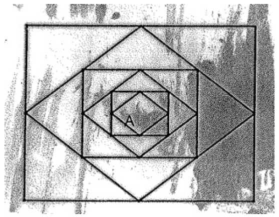
SGI





Command	Parameters	Description
A	display shape	Activate and display the indicated shape. The subsequent commands refer to this active shape
B		reset the deBugging switch
C	line/point no.	select the indicated line (or point) as the Current line (or point)
D	[line/point no.]	Delete the current [or indicated] line/point and renumber if necessary
E	[rule no.]	Enter a copy of the active shape as a side of the indicated shape rule. If no rule number is supplied, increment the <u>highest rule entered</u> by 1 to give the new rule number
ER	[rule no.]	Enter a copy of the left and right rule shapes as the indicated shape rule
F	[side] [rule no.]	Fetch a copy of the indicated side of the indicated shape rule onto the active shape. If no side is supplied, the entire shape rule is fetched onto the rule shapes. If no rule number is supplied, the <u>last rule entered</u> is fetched
G	production rules	enter the Generation phase. The indicated production rules are the only shape rules that can be referenced in the generation phase

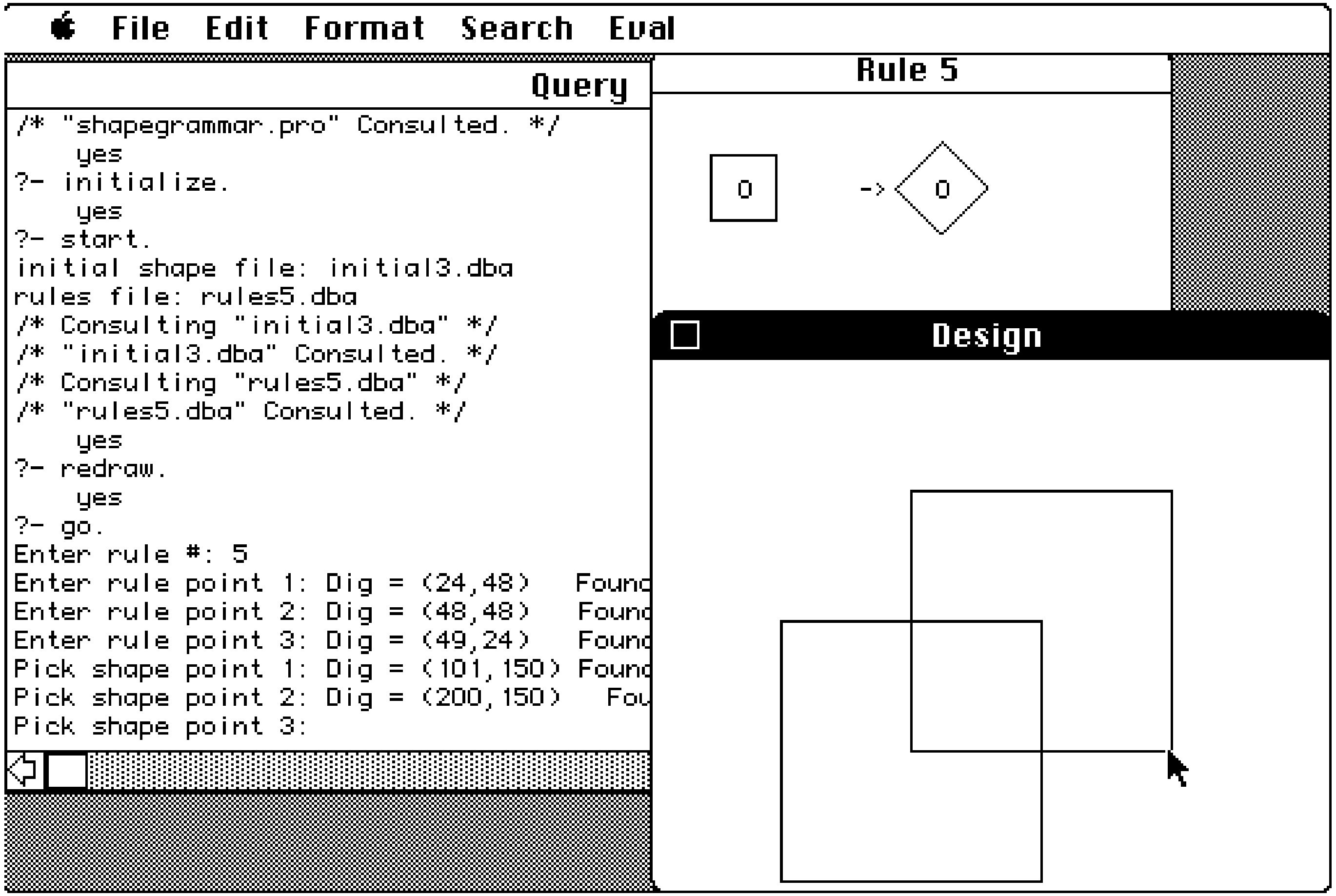




SG interpreter

Chase 1987

Chase S C, 1989, "Shapes and Shape Grammars: From Mathematical Model to Computer Implementation" *Environment and Planning B: Planning and Design* ***16 215-242***

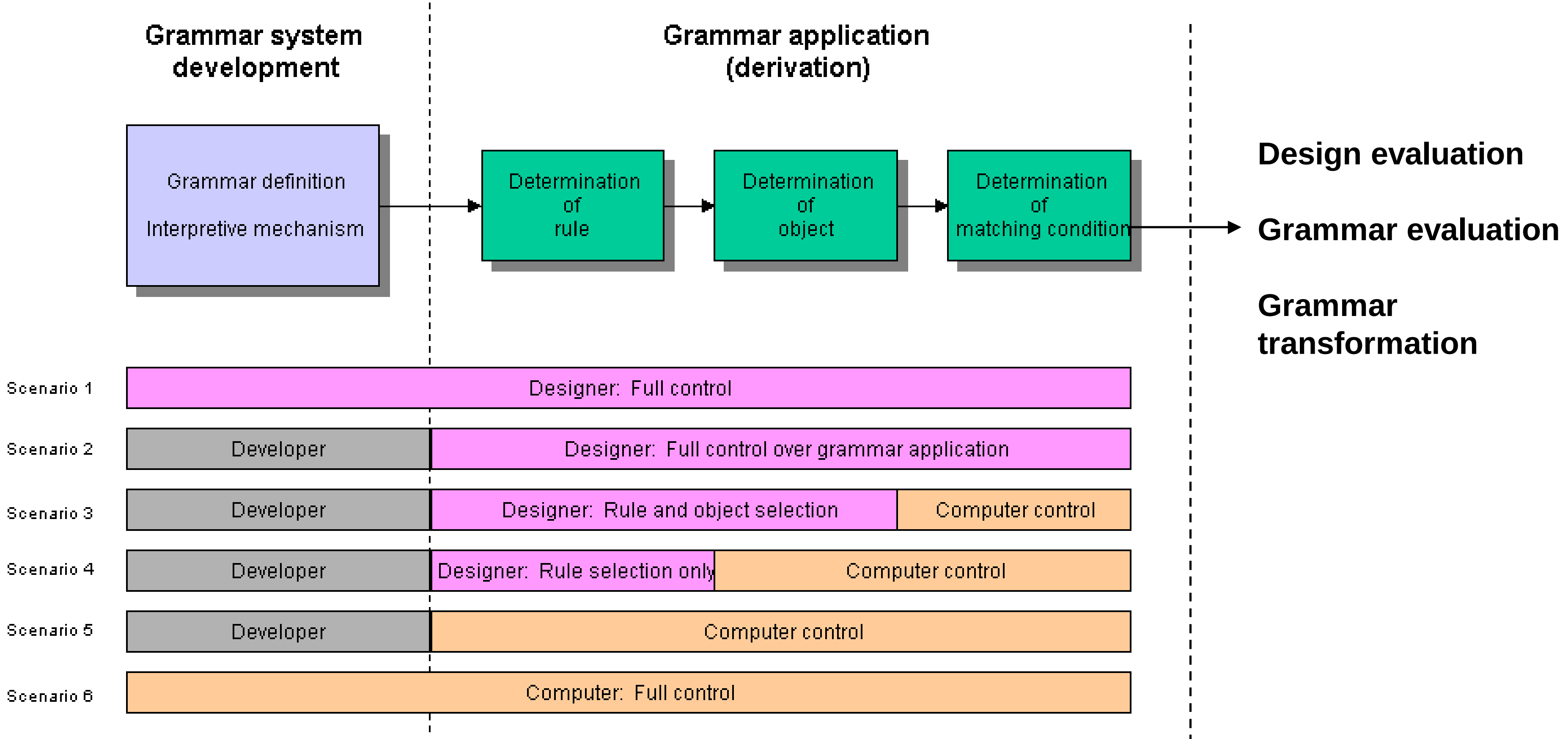


```
/* "shapegrammar.pro" Consulted. */
    yes
?- initialize.
    yes
?- start.
initial shape file: initial3.dba
rules file: rules5.dba
/* Consulting "initial3.dba" */
/* "initial3.dba" Consulted. */
/* Consulting "rules5.dba" */
/* "rules5.dba" Consulted. */
    yes
?- redraw.
    yes
?- go.
Enter rule #: 5
Enter rule point 1: Dig = (24,48)   Founc
Enter rule point 2: Dig = (48,48)   Founc
Enter rule point 3: Dig = (49,24)   Founc
Pick shape point 1: Dig = (101,150) Founc
Pick shape point 2: Dig = (200,150)   Fou
Pick shape point 3:
```

Interface/Interaction

Grammar use & interaction

Chase 2002



Grammar system development

Grammar application (derivation)

Grammar definition

Interpretive mechanism

Determination of rule

Determination of object

Determination of matching condition

Design evaluation

Grammar evaluation

Grammar transformation

Scenario 1: Designer: Full control

Scenario 2: Developer | Designer: Full control over grammar application

Scenario 3: Developer | Designer: Rule and object selection | Computer control

Scenario 4: Developer | Designer: Rule selection only | Computer control

Scenario 5: Developer | Computer control

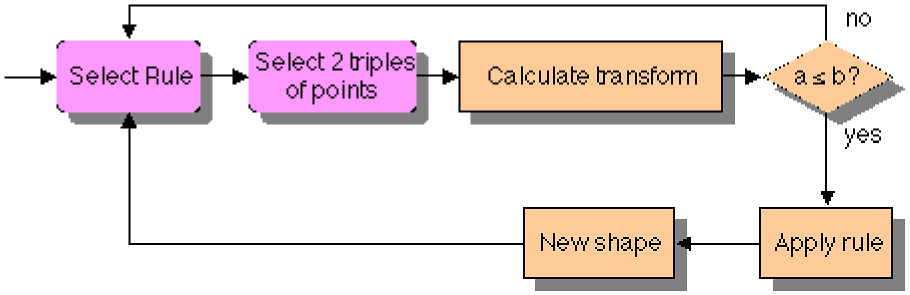
Scenario 6: Computer: Full control

Chase S C, 2002, "A model for user interaction in grammar-based design systems" *Automation in Construction* ***11* *161-172***

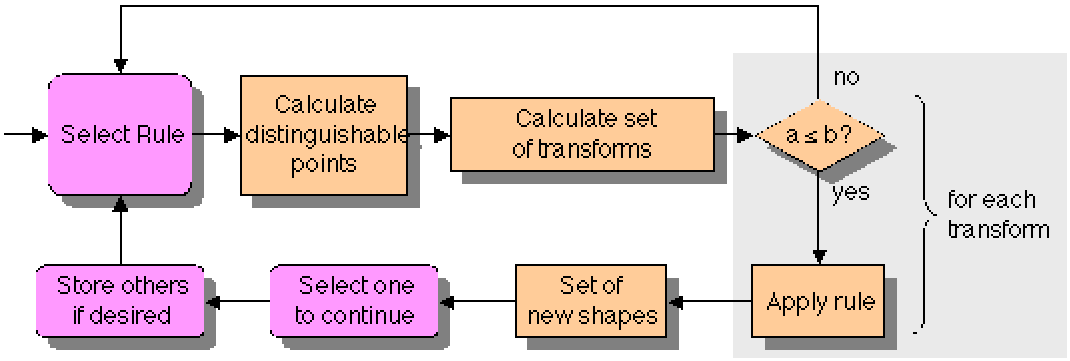
Grammar interaction

Chase 1987 & 2002

a) Manual mode (Scenario 2)

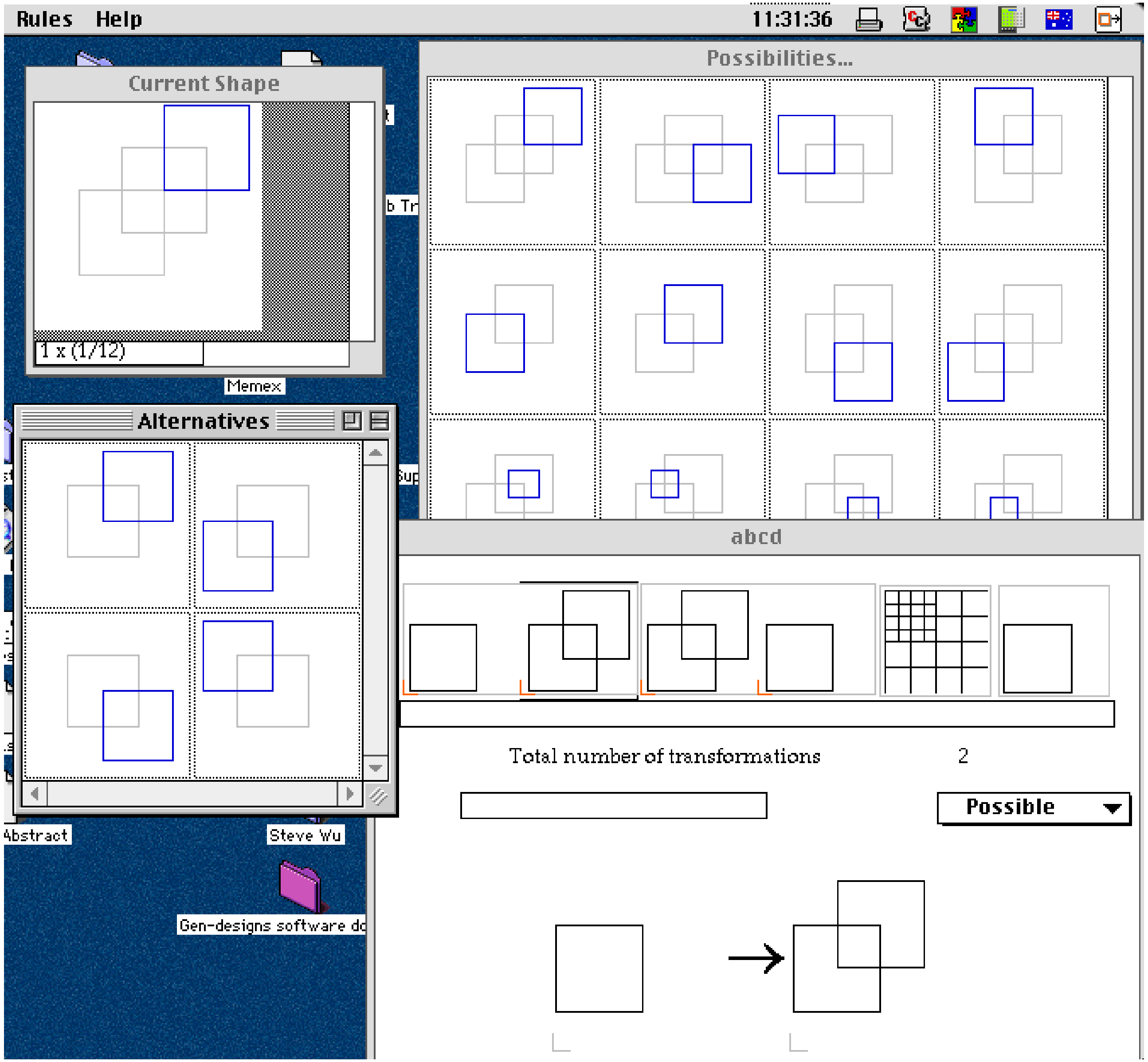


b) Semi-automatic mode (Scenario 4)



GEdit

Tapia 1996

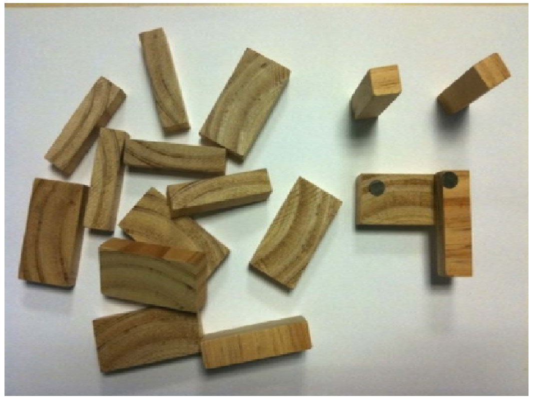


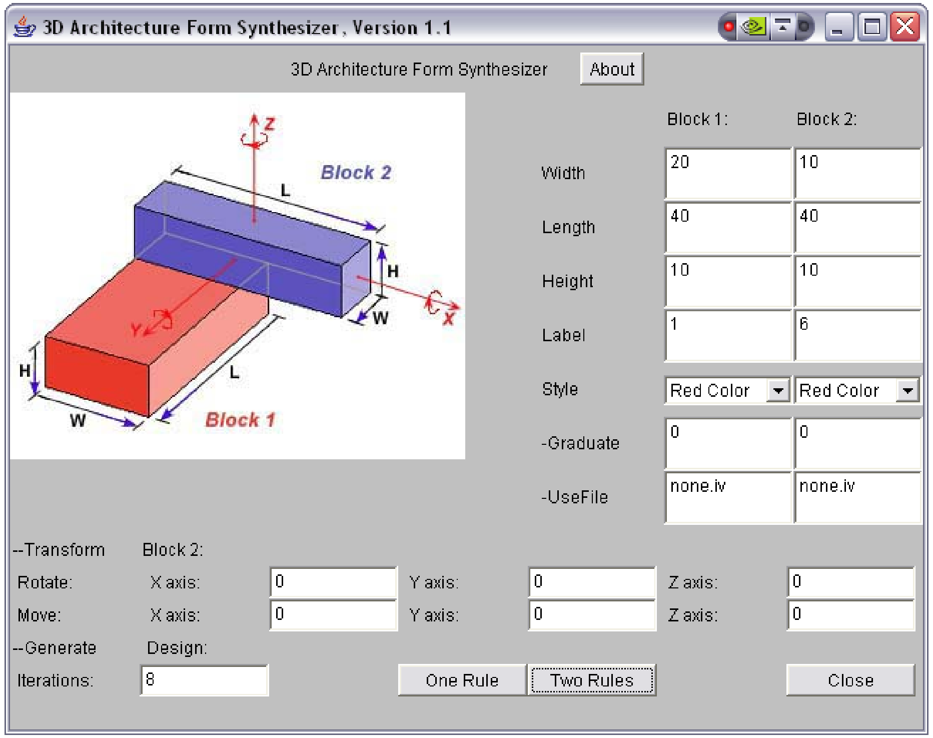
Total number of transformations 2

Tapia M, 1999, "A visual implementation of a shape grammar system" *Environment and Planning B: Planning and Design* ***26* 59-73**

3D Shaper

Wang 1998





3D Architecture Form Synthesizer, Version 1.1
3D Architecture Form Synthesizer
About
Z
Block 2
L
H
W
X
Y
H
L
W
Block 1
One Rule
Two Rules
Close

	Block 1:	Block 2:
Width	20	10
Length	40	40
Height	10	10
Label	1	6
Style	Red Color	Red Color
-Graduate	0	0
-UseFile	none.iv	none.iv

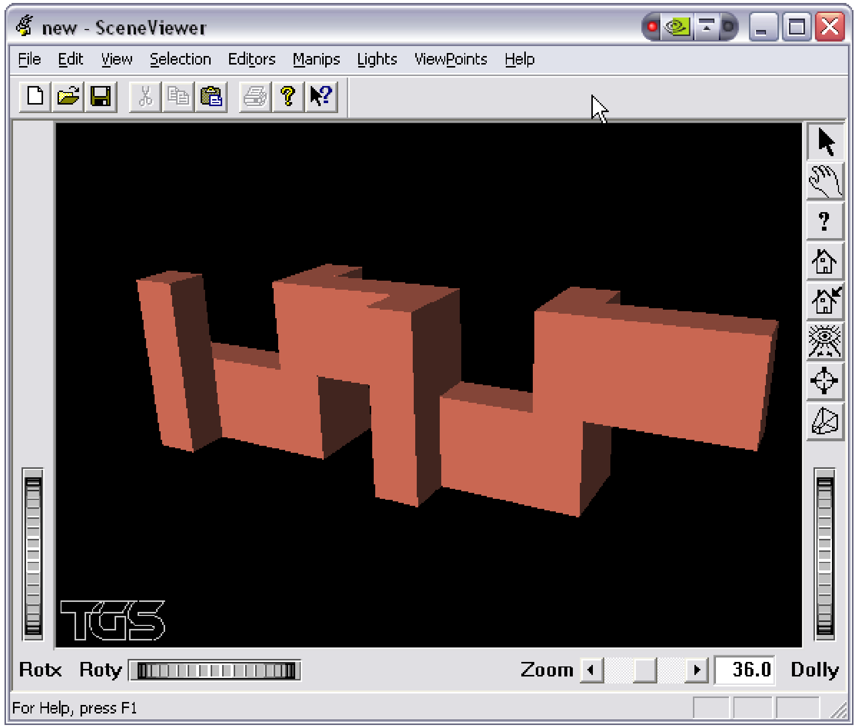
--Transform Block 2:

Rotate: X axis: 0 Y axis: 0 Z axis: 0

Move: X axis: 0 Y axis: 0 Z axis: 0

--Generate Design:

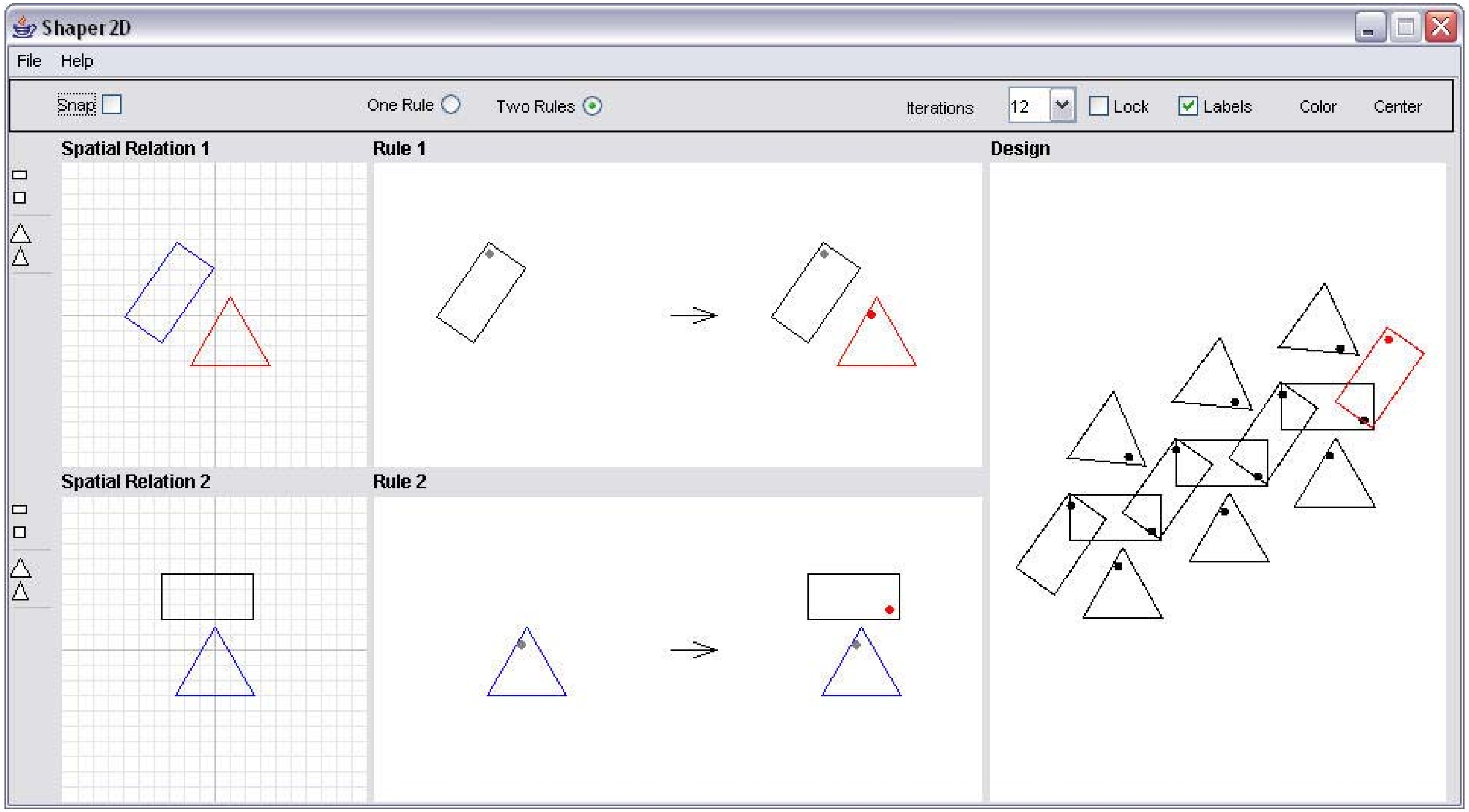
Iterations: 8



Wang Y, Duarte J P, 2002, "Automatic generation and fabrication of designs" *Automation in Construction* ***11* 291-302**

Shaper 2D

McGill 2001



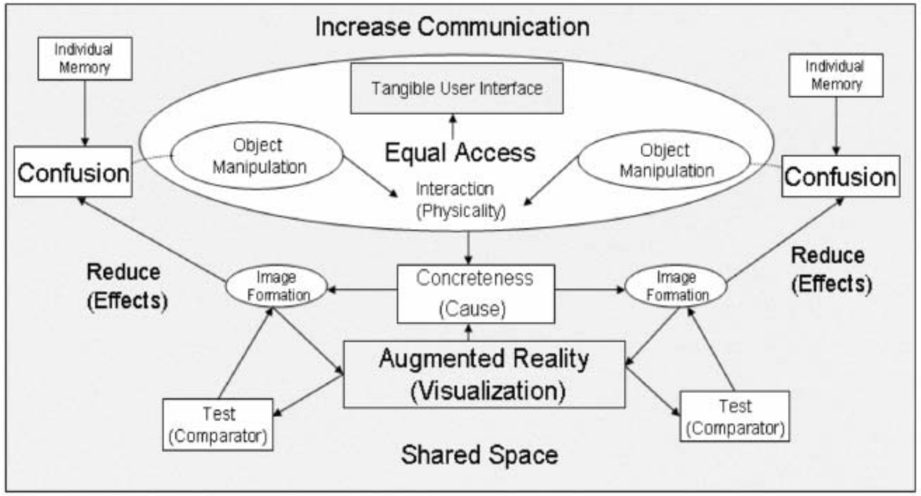
Snap □ One Rule ○ Two Rules ● Iterations 12 □ Lock ☑ Labels

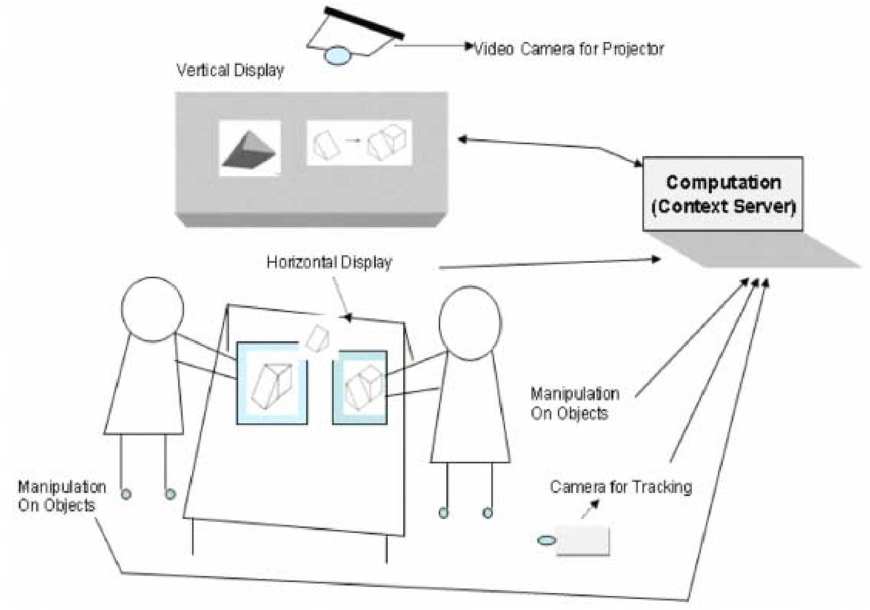
McGill M C, 2002, "Shaper2D: Visual Software for Learning Shape Grammars", in *Design e-ducation: Connecting the Real and the Virtual, Proceedings of the 20th Conference on Education in Computer Aided Architectural Design in Europe Eds K Koszewski, S Wrona (eCAADe, Warsaw) pp 148-151*

Designing With Vision

http://design.open.ac.uk/DV

SG & Tangible Augmented Reality
Chen et al. 2009





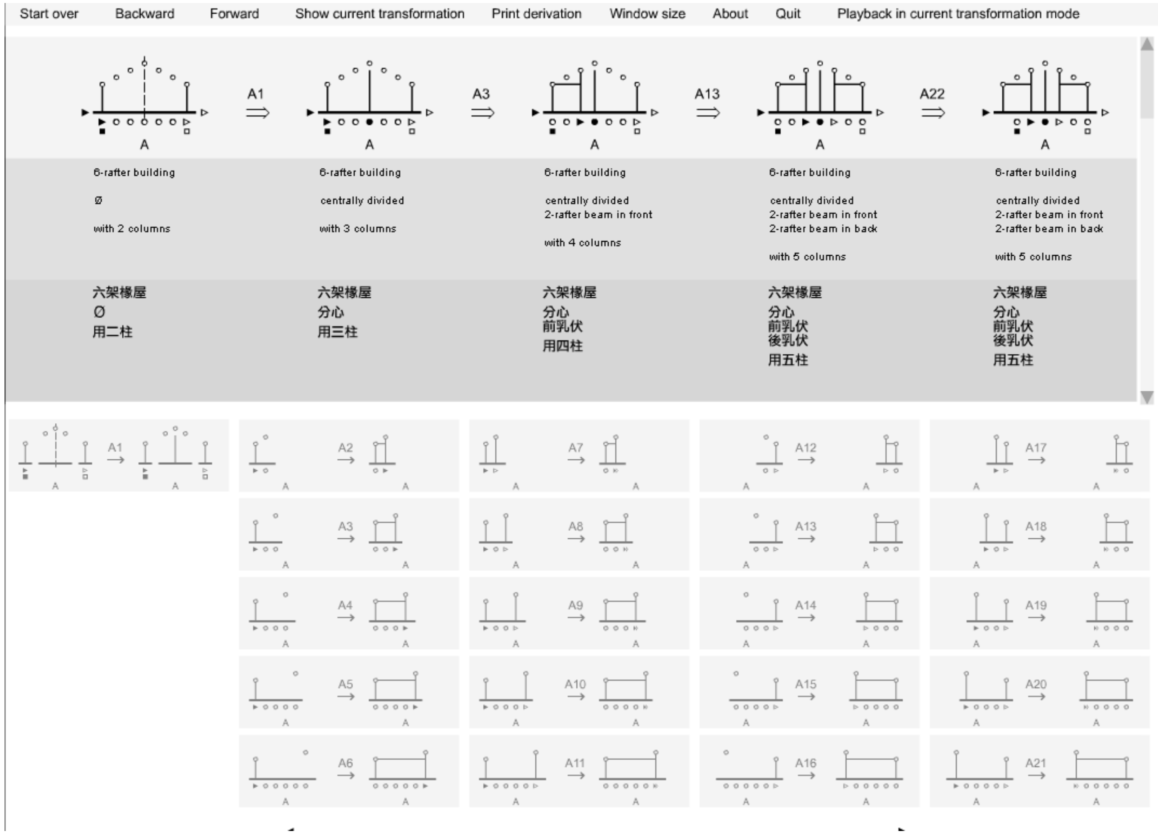
Chen I R, Wang X, Wang W 2009, "Bridging Shape Grammar and Tangible Augmented Reality into Collaborative Design Learning" in *Proceedings of the 2009 13th International Conference on Computer Supported Cooperative Work in Design* (IEEE) 468-473

Extensions

Yingzao fashi grammar

Li 2002

Non-geometric attributes



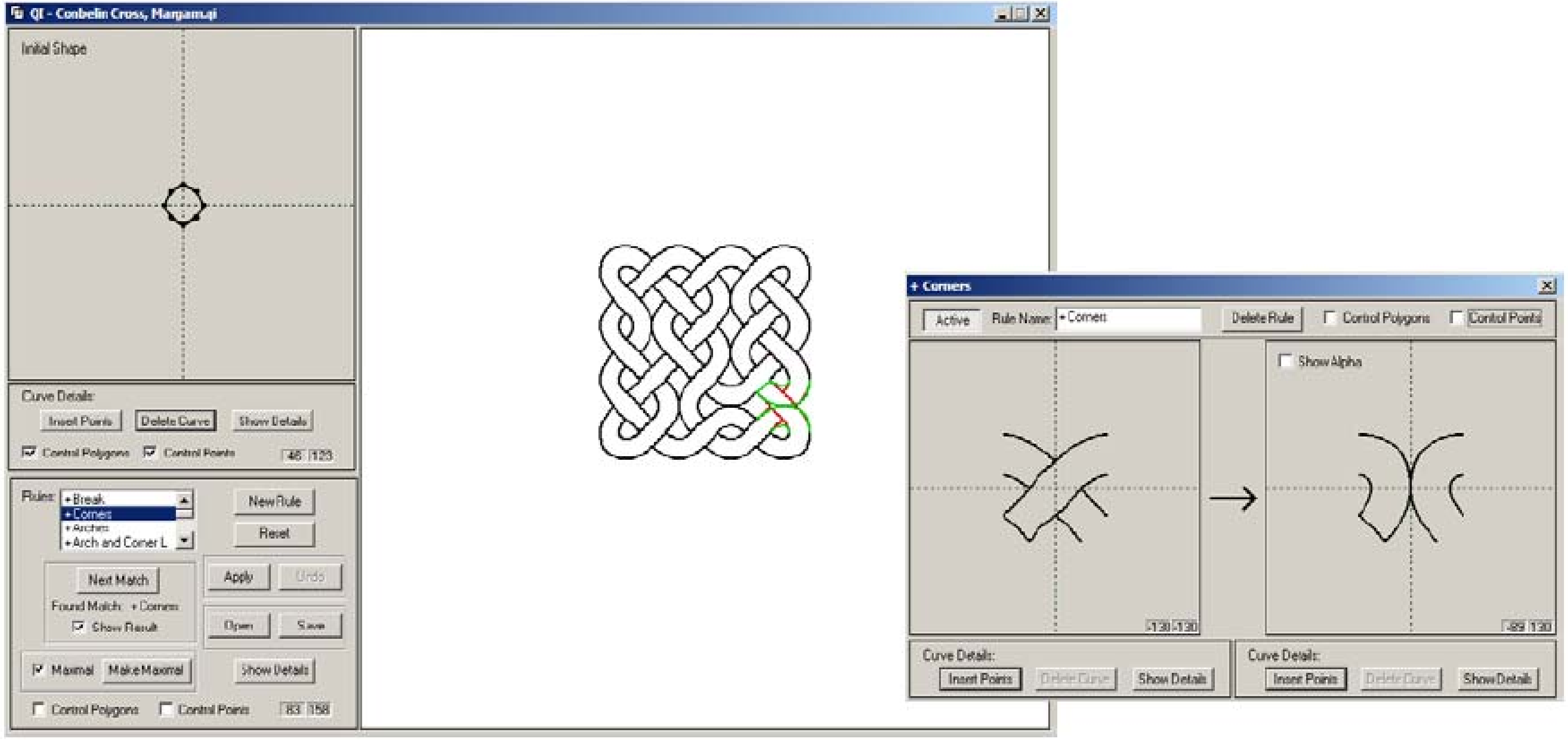
6-rafter building Ø with 2 columns	6-rafter building centrally divided with 3 columns	6-rafter building centrally divided 2-rafter beam in front with 4 columns	6-rafter building centrally divided 2-rafter beam in front 2-rafter beam in back with 5 columns	6-rafter building centrally divided 2-rafter beam in front 2-rafter beam in back with 5 columns
六架椽屋 Ø 用二柱	六架椽屋 分心 用三柱	六架椽屋 分心 前乳伏 用四柱	六架椽屋 分心 前乳伏 後乳伏 用五柱	六架椽屋 分心 前乳伏 後乳伏 用五柱

Li A I-K, 2002, "A prototype interactive simulated shape grammar", in *Design e-ducation: Connecting the Real and the Virtual, Proceedings of the 20th Conference on Education in Computer Aided Architectural Design in Europe Eds K Koszewski, S Wrona (eCAADe, Warsaw) pp 314-317*

QI (curves)

Jowers 2006

Jowers I, 2006, *Computation with curved shapes: Towards freeform shape generation in design*, PhD thesis, The Open University



QI - Conbelin Cross, Margam.qi

Initial Shape

Curve Details:

☑ Control Polygons ☑ Control Points 46 123

Rules: +Break +Corners +Arches +Arch and Corner L

Found Match: +Corners

☑ Show Result

☑ Maximal

☐ Control Polygons ☐ Control Points 83 158

+ Corners

Rule Name: +Corners

☐ Control Polygons ☐ Control Points

☐ Show Alpha

-130 -130

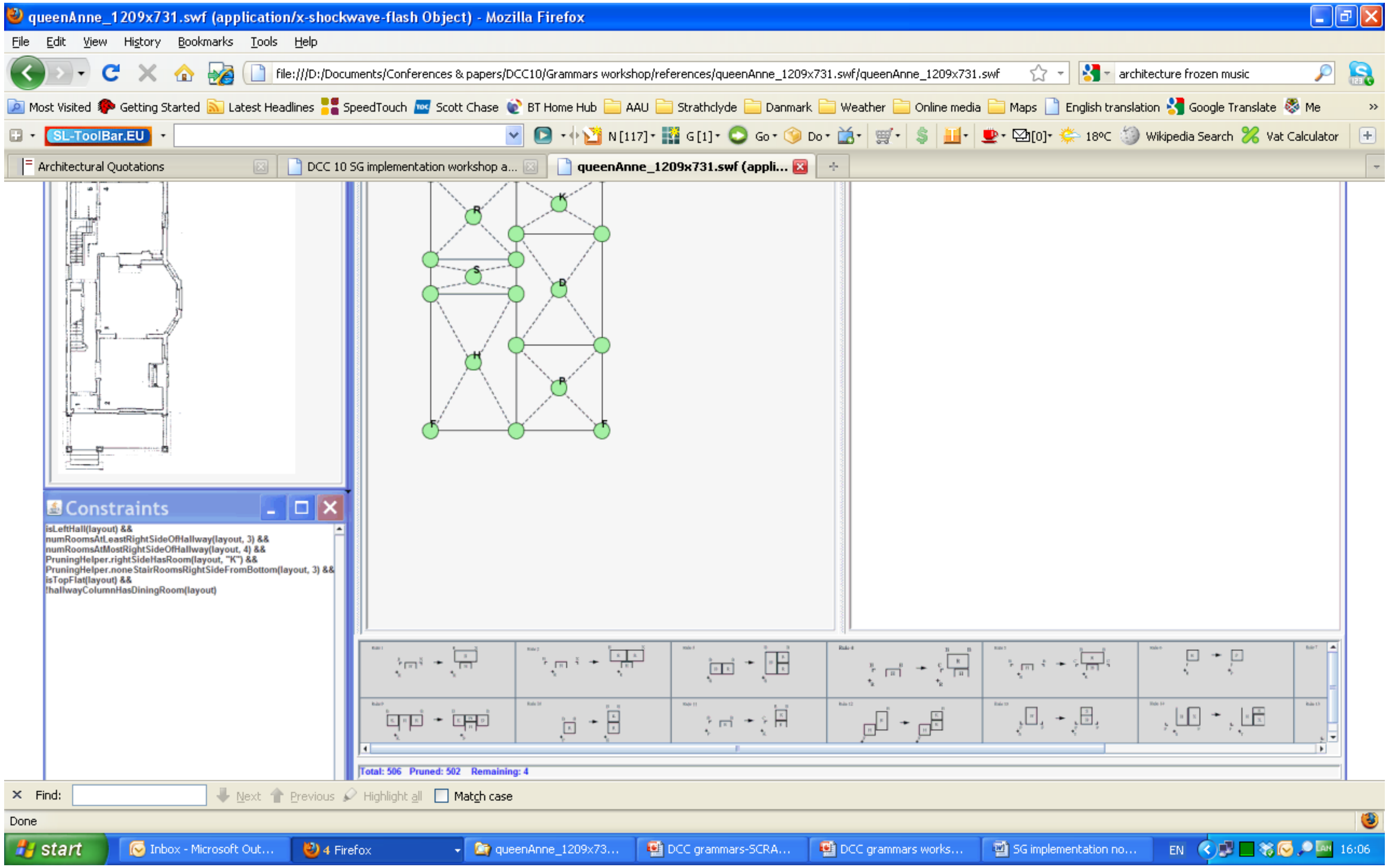
-89 130

Curve Details:

Curve Details:

Parametric SG interpreter

Krishnamurti 2010


queenAnne_1209x731.swf (application/x-shockwave-flash Object) - Mozilla Firefox
File Edit View History Bookmarks Tools Help
file:///D:/Documents/Conferences & papers/DCC10/Grammars workshop/references/queenAnne_1209x731.swf/queenAnne_1209x731.swf
architecture frozen music
Most Visited Getting Started Latest Headlines SpeedTouch Scott Chase BT Home Hub AAU Strathclyde Danmark Weather Online media Maps English translation Google Translate Me
SL-ToolBar.EU
N [117] G [1] Go Do 18°C Wikipedia Search Vat Calculator
Architectural Quotations
DCC 10 SG implementation workshop a...
queenAnne_1209x731.swf (appli...
R
K
S
D
H
P
F
F
F
Constraints
Find: Next Previous Highlight all Match case
Done
start
Inbox - Microsoft Out...
4 Firefox
queenAnne_1209x73...
DCC grammars-SCRA...
DCC grammars works...
SG implementation no...
EN
16:06

```
isLeftHall(layout) &&
numRoomsAtLeastRightSideOfHallway(layout, 3) &&
numRoomsAtMostRightSideOfHallway(layout, 4) &&
PruningHelper.rightSideHasRoom(layout, "K") &&
PruningHelper.noneStairRoomsRightSideFromBottom(layout, 3) &&
isTopFlat(layout) &&
!hallwayColumnHasDiningRoom(layout)
```

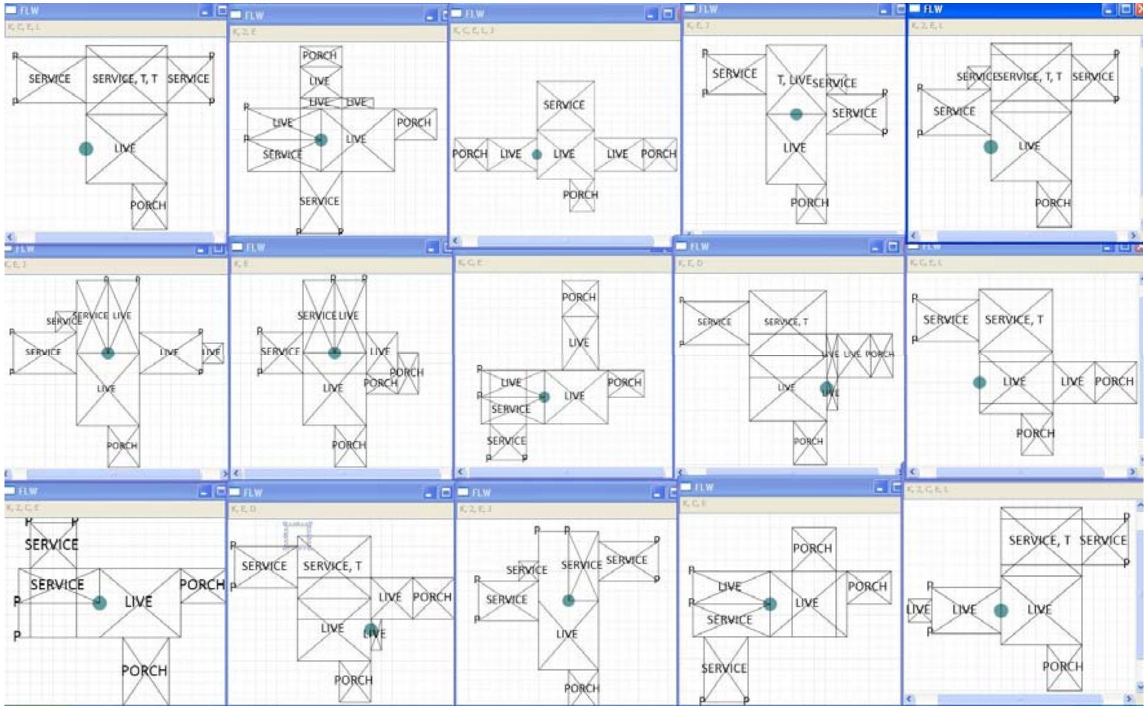
Total: 506 Pruned: 502 Remaining: 4

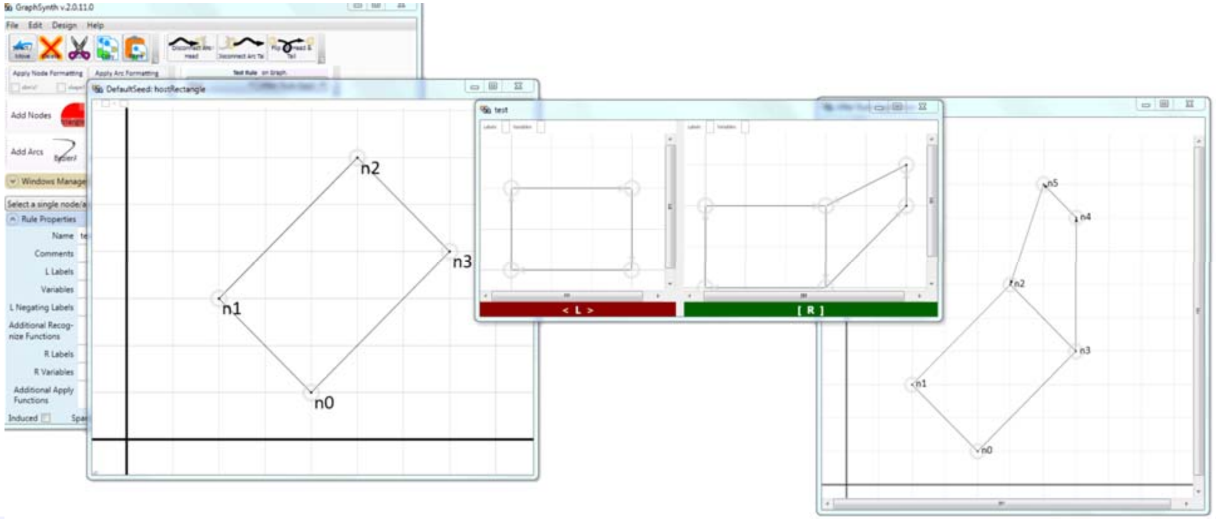
Graph grammars

- Schmidt (from PhD 1995)
- Campbell

GraphSynth

Campbell 2010





http://www.graphsynth.com

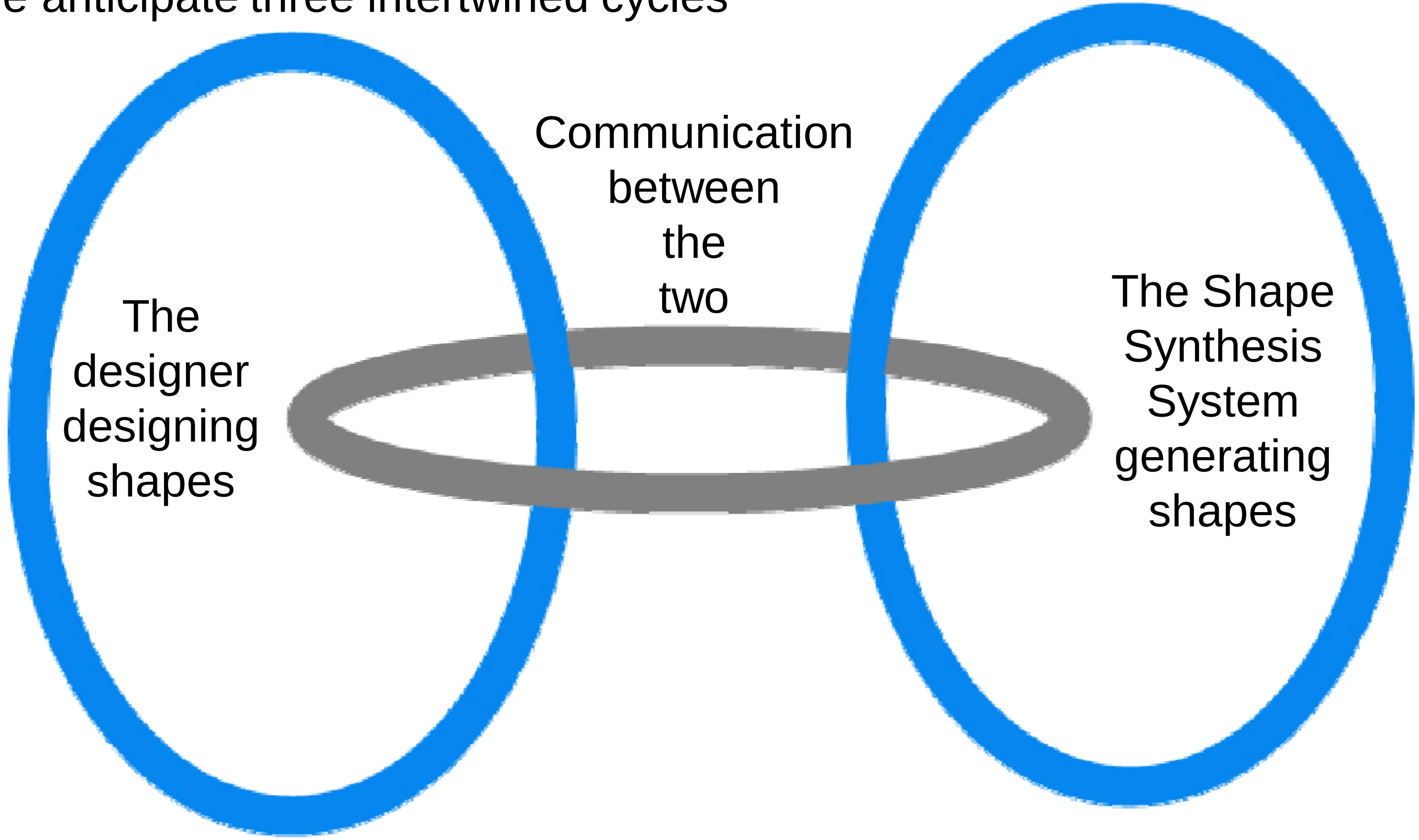
Integration with design & production processes

Design Synthesis & Shape Generation

McKay et al. 2007-08

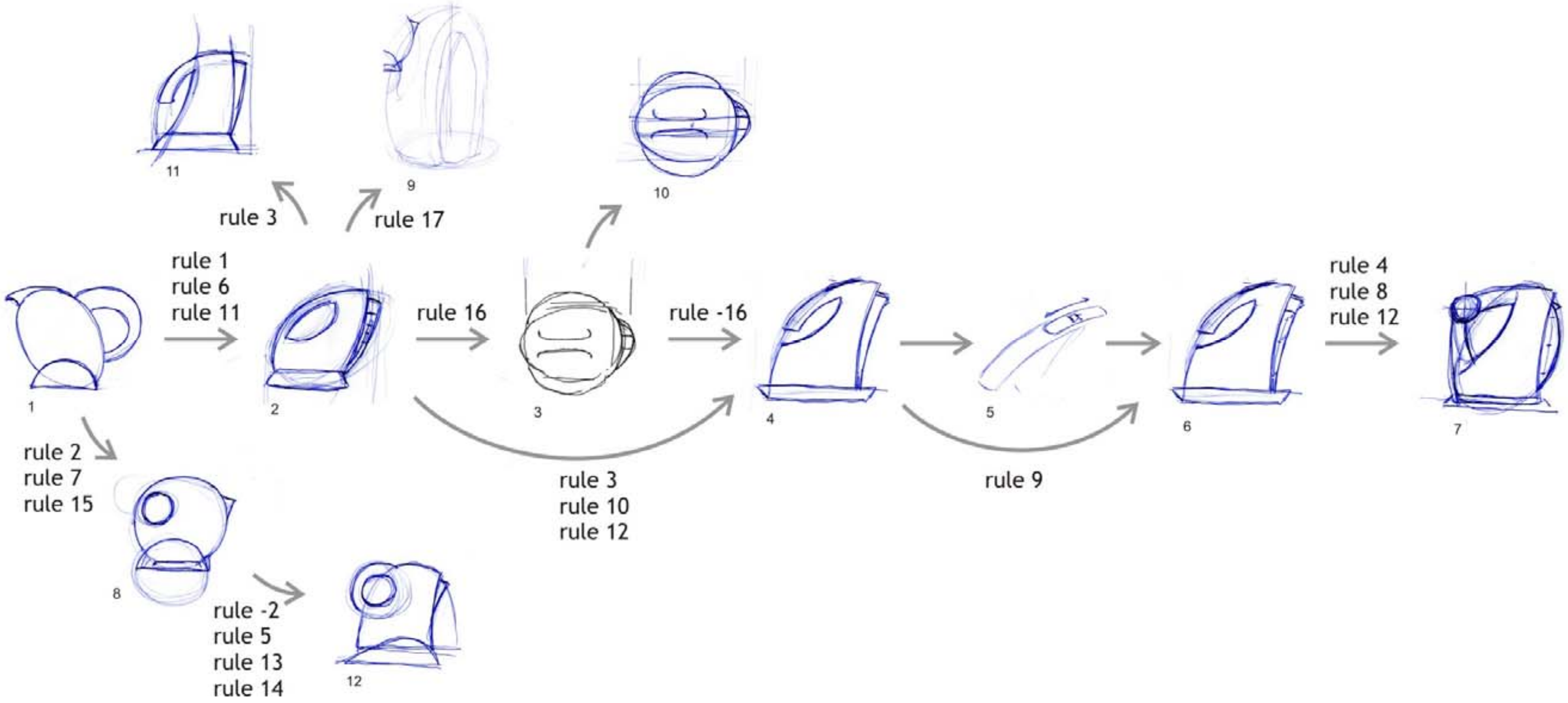
http://www.engineering.leeds.ac.uk/dssg

… we anticipate three intertwined cycles


The designer designing shapes
Communication between the two
The Shape Synthesis System generating shapes

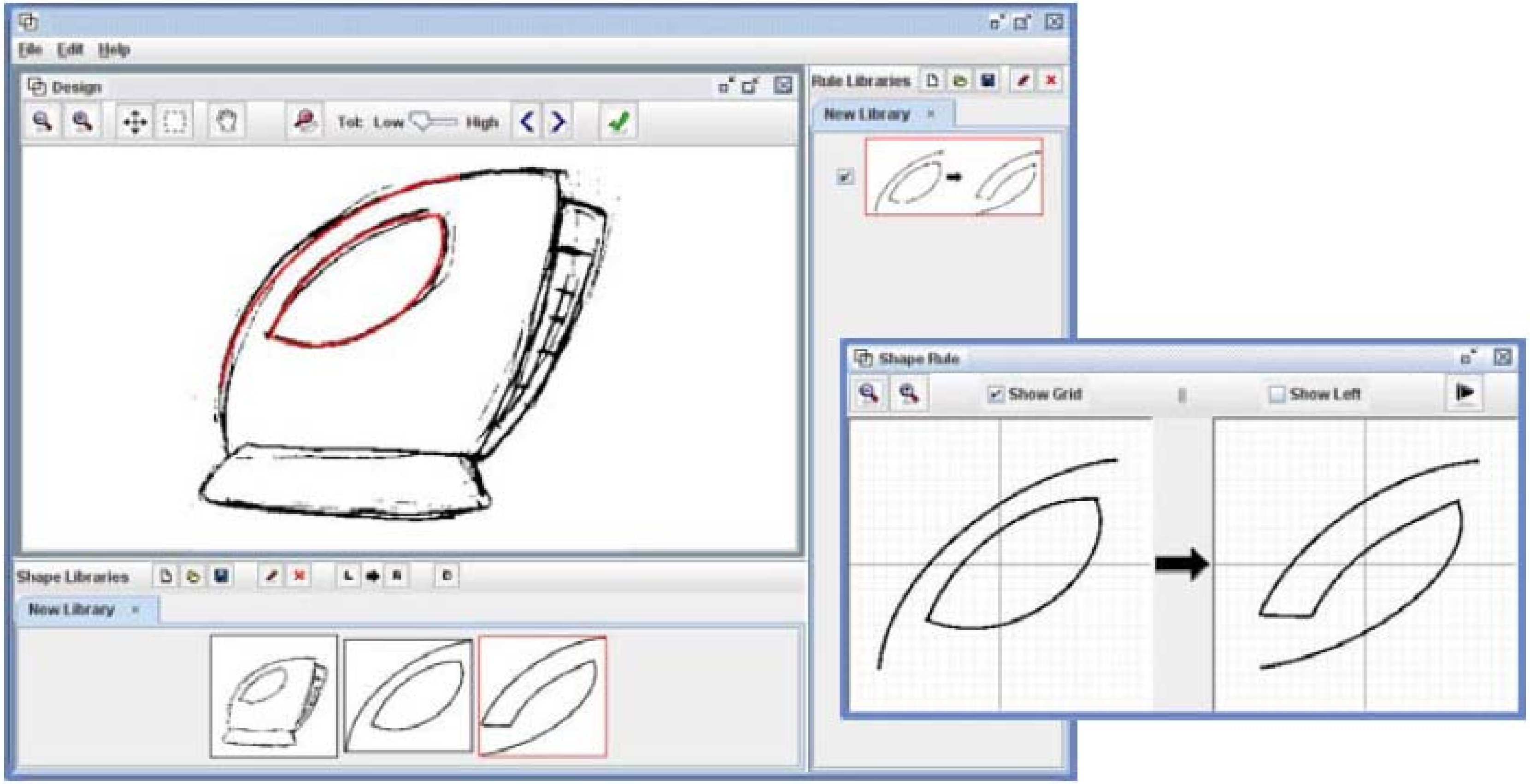
Design Synthesis & Shape Generation

McKay et al. 2007-08



Design Synthesis & Shape Generation

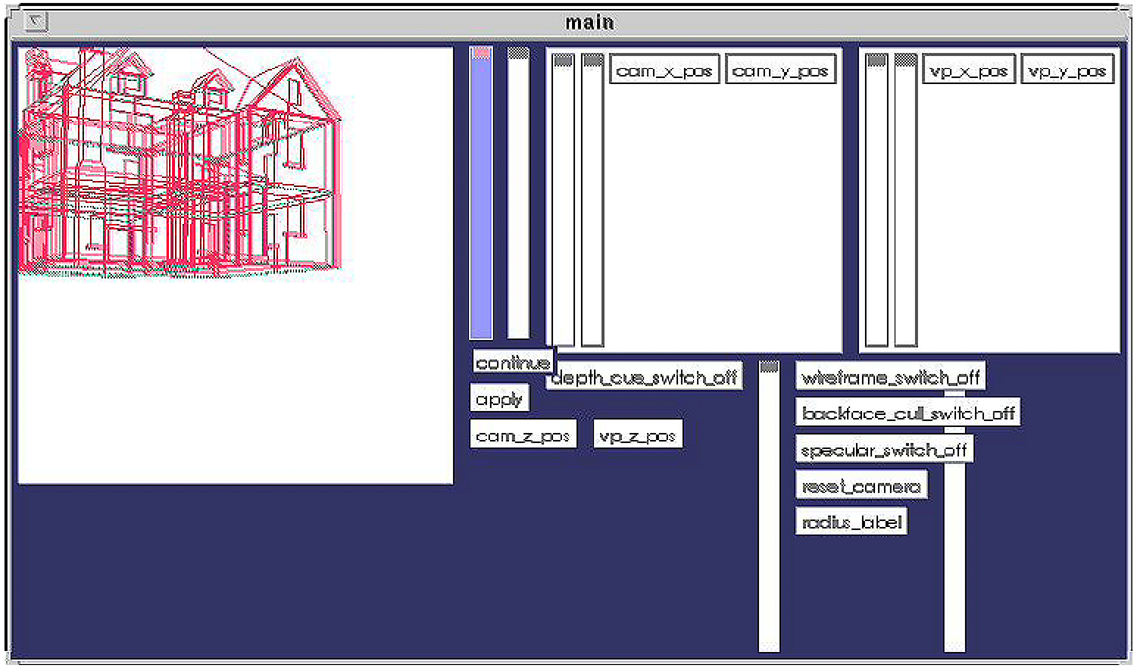
McKay et al. 2007-08



Industrial strength interpreters

Genesis-PhD

Heisserman 1991



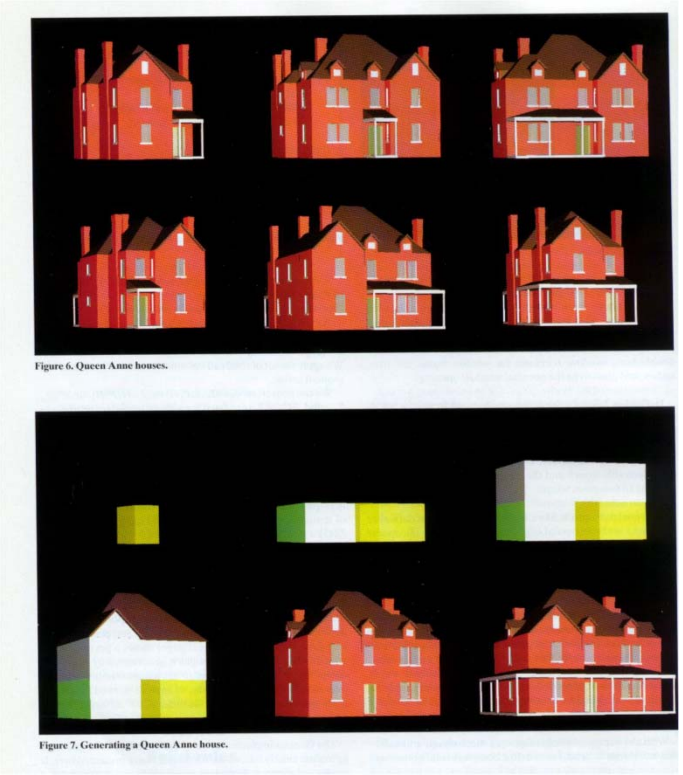


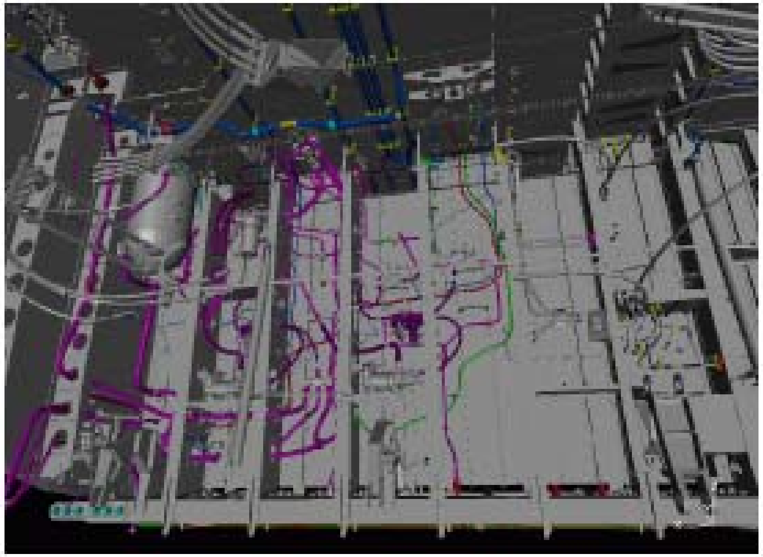
Figure 6. Queen Anne houses.

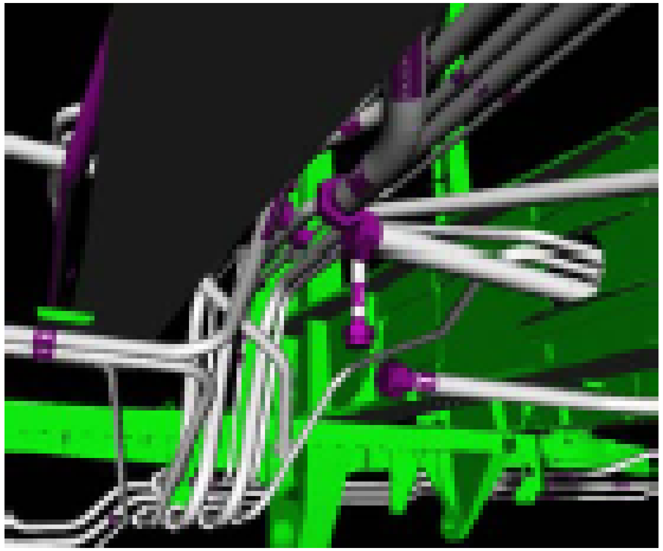
Figure 7. Generating a Queen Anne house.

Heisserman J, 1994, "Generative Geometric Design" *IEEE Computer Graphics and Applications* ***14 37-45***

Genesis-Boeing

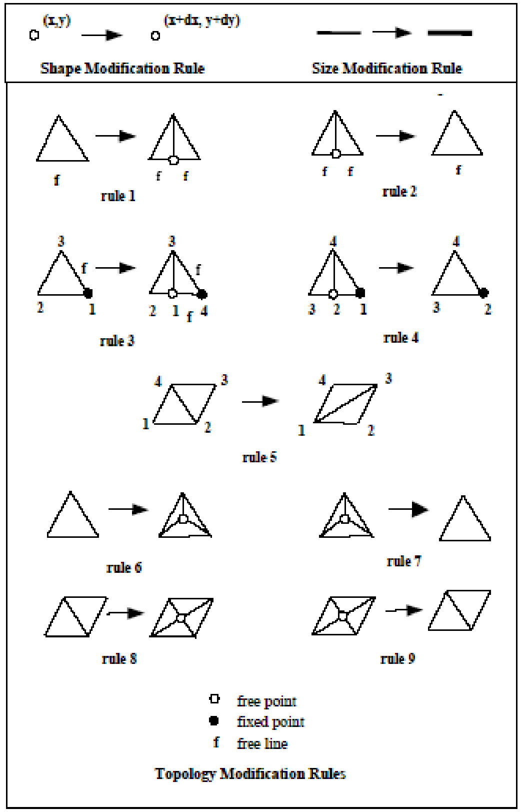
Heisserman since 1991



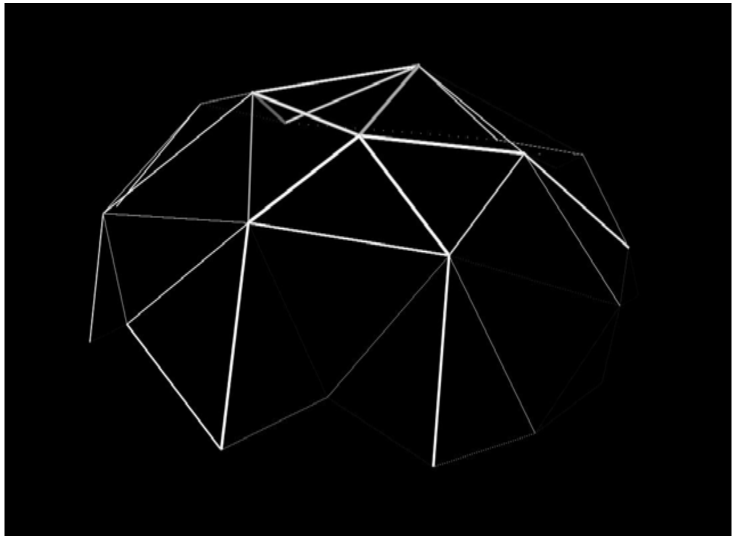


EifForm

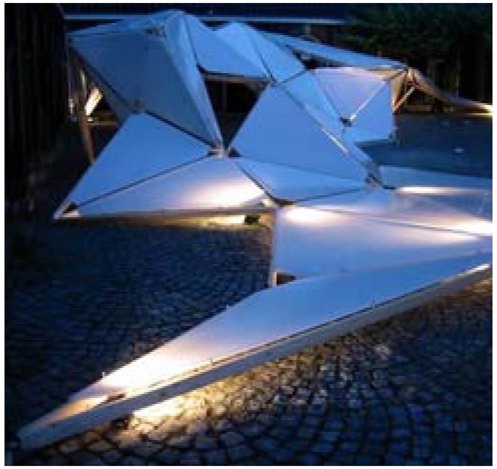
Shea from 1997



Planar truss grammar



Dome

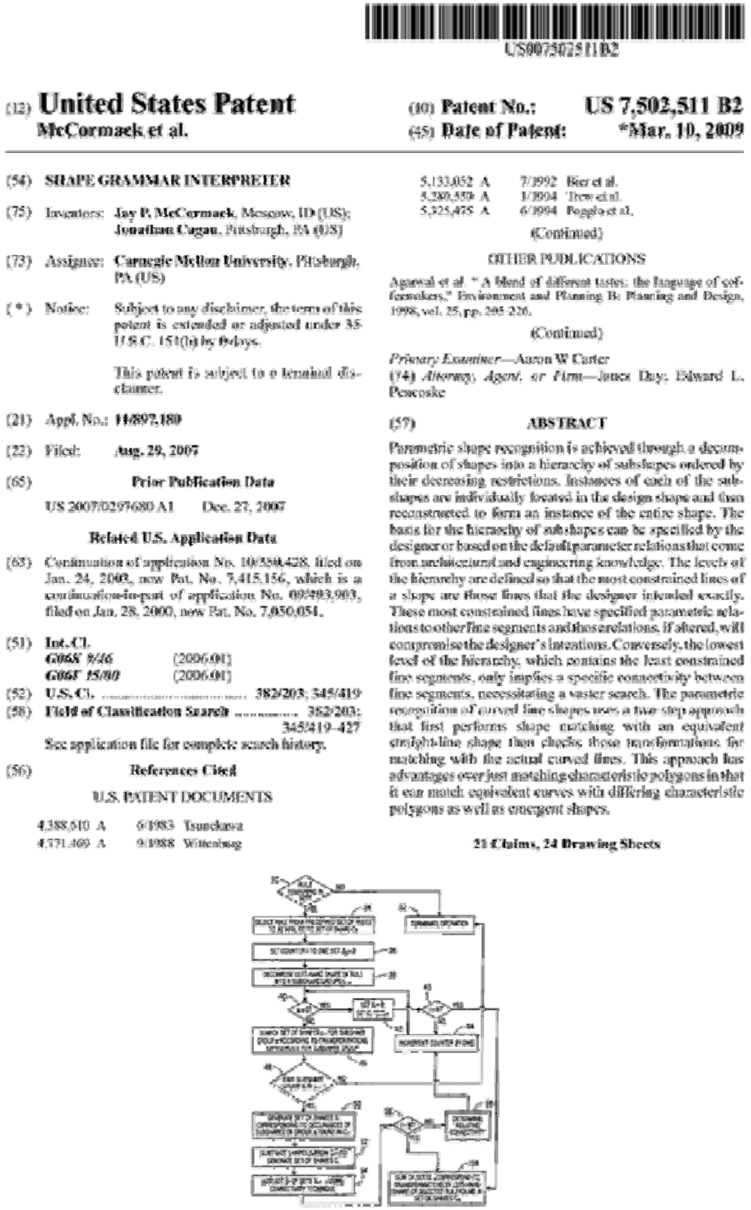


Canopy/landscape

Shea K, 2002, "Creating Synthesis Partners" *Architectural Design* ***72* 42-45**

SG interpreter patents

McCormick & Cagan 2006/9



US007502511B2

(12) **United States Patent**
McCormack et al.

(10) **Patent No.: US 7,502,511 B2**
(45) **Date of Patent: *Mar. 10, 2009**

(54) **SHAPE GRAMMAR INTERPRETER**

(75) Inventors: **Jay P. McCormack**, Moscow, ID (US); **Jonathan Cagan**, Pittsburgh, PA (US)

(73) Assignee: **Carnegie Mellon University**, Pittsburgh, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/897,180**

(22) Filed: **Aug. 29, 2007**

(65) **Prior Publication Data**

US 2007/0297680 A1 Dec. 27, 2007

Related U.S. Application Data

(63) Continuation of application No. 10/350,428, filed on Jan. 24, 2003, now Pat. No. 7,415,156, which is a continuation-in-part of application No. 09/493,903, filed on Jan. 28, 2000, now Pat. No. 7,050,051.

(51) **Int. Cl.**

G06K 9/46	(2006.01)
G06F 15/00	(2006.01)

(52) **U.S. Cl.** **382/203; 345/419**
(58) **Field of Classification Search** 382/203; 345/419-427
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,388,610 A	6/1983	Tsunekawa
4,771,469 A	9/1988	Wittenburg
5,133,052 A	7/1992	Bier et al.
5,280,530 A	1/1994	Trew et al.
5,325,475 A	6/1994	Poggio et al.

(Continued)

OTHER PUBLICATIONS

Agarwal et al. " A blend of different tastes: the language of coffeemakers," Environment and Planning B: Planning and Design, 1998, vol. 25, pp. 205-226.

(Continued)

Primary Examiner—Aaron W Carter
(74) *Attorney, Agent, or Firm*—Jones Day; Edward L. Pencoske

(57) **ABSTRACT**

Parametric shape recognition is achieved through a decomposition of shapes into a hierarchy of subshapes ordered by their decreasing restrictions. Instances of each of the subshapes are individually located in the design shape and then reconstructed to form an instance of the entire shape. The basis for the hierarchy of subshapes can be specified by the designer or based on the default parameter relations that come from architectural and engineering knowledge. The levels of the hierarchy are defined so that the most constrained lines of a shape are those lines that the designer intended exactly. These most constrained lines have specified parametric relations to other line segments and these relations, if altered, will compromise the designer's intentions. Conversely, the lowest level of the hierarchy, which contains the least constrained line segments, only implies a specific connectivity between line segments, necessitating a vaster search. The parametric recognition of curved line shapes uses a two-step approach that first performs shape matching with an equivalent straight-line shape then checks those transformations for matching with the actual curved lines. This approach has advantages over just matching characteristic polygons in that it can match equivalent curves with differing characteristic polygons as well as emergent shapes.

21 Claims, 24 Drawing Sheets

http://www.freepatentsonline.com/7050051.html
http://www.freepatentsonline.com/7502511.html

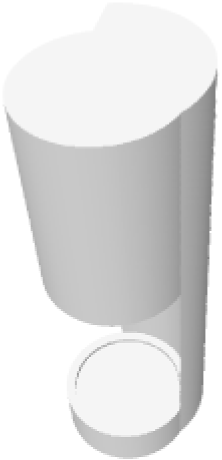
Specific design applications

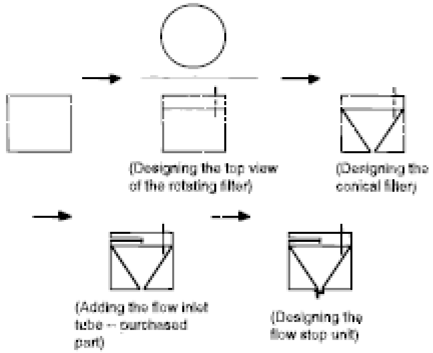
Specific design applications

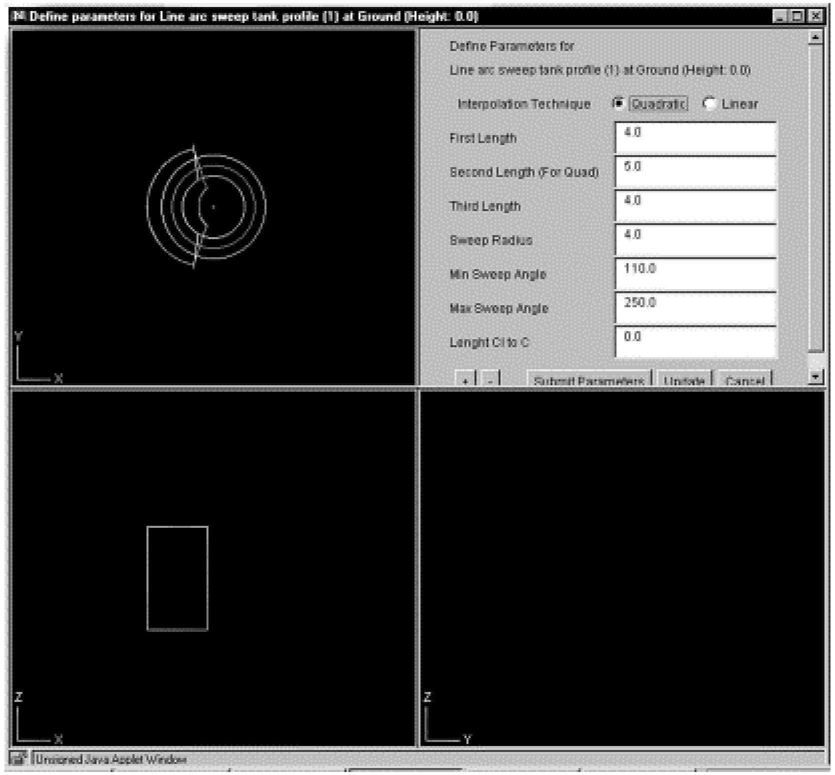
- Product development
  - Coffeemaker (Agarwal & Cagan, 1998)
  - Dove (Chau, 2002)
  - Harley Davidson (Pugliese & Cagan, 2002)
  - Buick (McCormack et al., 2004)
  - Coca-Cola (Chen, 2005)
  - General shampoo bottle grammar (Chen 2005)
- Architecture
  - MALAG (Duarte 2005)

Coffee maker grammar

Agarwal et al 1999




(Designing the top view of the rotating filter)
(Designing the conical filter)
(Adding the flow inlet tube -- purchased part)
(Designing the flow stop unit)



Define parameters for Line arc sweep tank profile (1) at Ground (Height: 0.0)

Define Parameters for
Line arc sweep tank profile (1) at Ground (Height: 0.0)

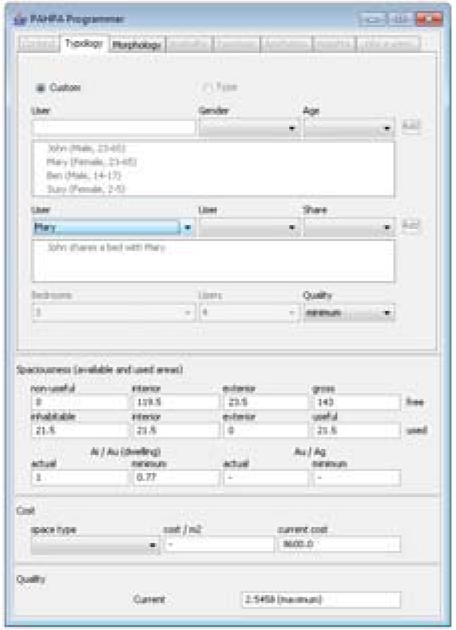
Interpolation Technique ● Quadratic ○ Linear

First Length: 4.0
Second Length (For Quad): 5.0
Third Length: 4.0
Sweep Radius: 4.0
Min Sweep Angle: 110.0
Max Sweep Angle: 250.0
Lenght Cl to C: 0.0

Agarwal M, Cagan J, 1998, "A Blend of Different Tastes: The Language of Coffee Makers" *Environment and Planning B: Planning and Design **25 205-226***

MALAG

Duarte 2005



● Custom ○ Type

User | Gender | Age | Add

John (Male, 23-65)
Mary (Female, 23-65)
Ben (Male, 14-17)
Suzy (Female, 2-5)

User | User | Share | Add

Mary

John shares a bed with Mary

Bedrooms: 3 | Users: 4 | Quality: minimum

Spaciousness (available and used areas)

non-useful	interior	exterior	gross	
0	119.5	23.5	143	free
inhabitable	interior	exterior	useful	
21.5	21.5	0	21.5	used

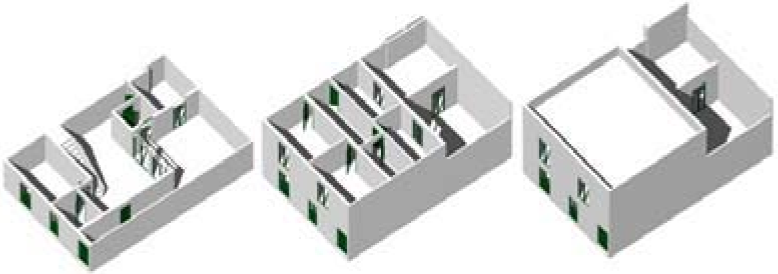
Ai / Au (dwelling)		Au / Ag	
actual	minimum	actual	minimum
1	0.77	-	-

Cost

space type | cost / m2: - | current cost: 8600.0

Quality

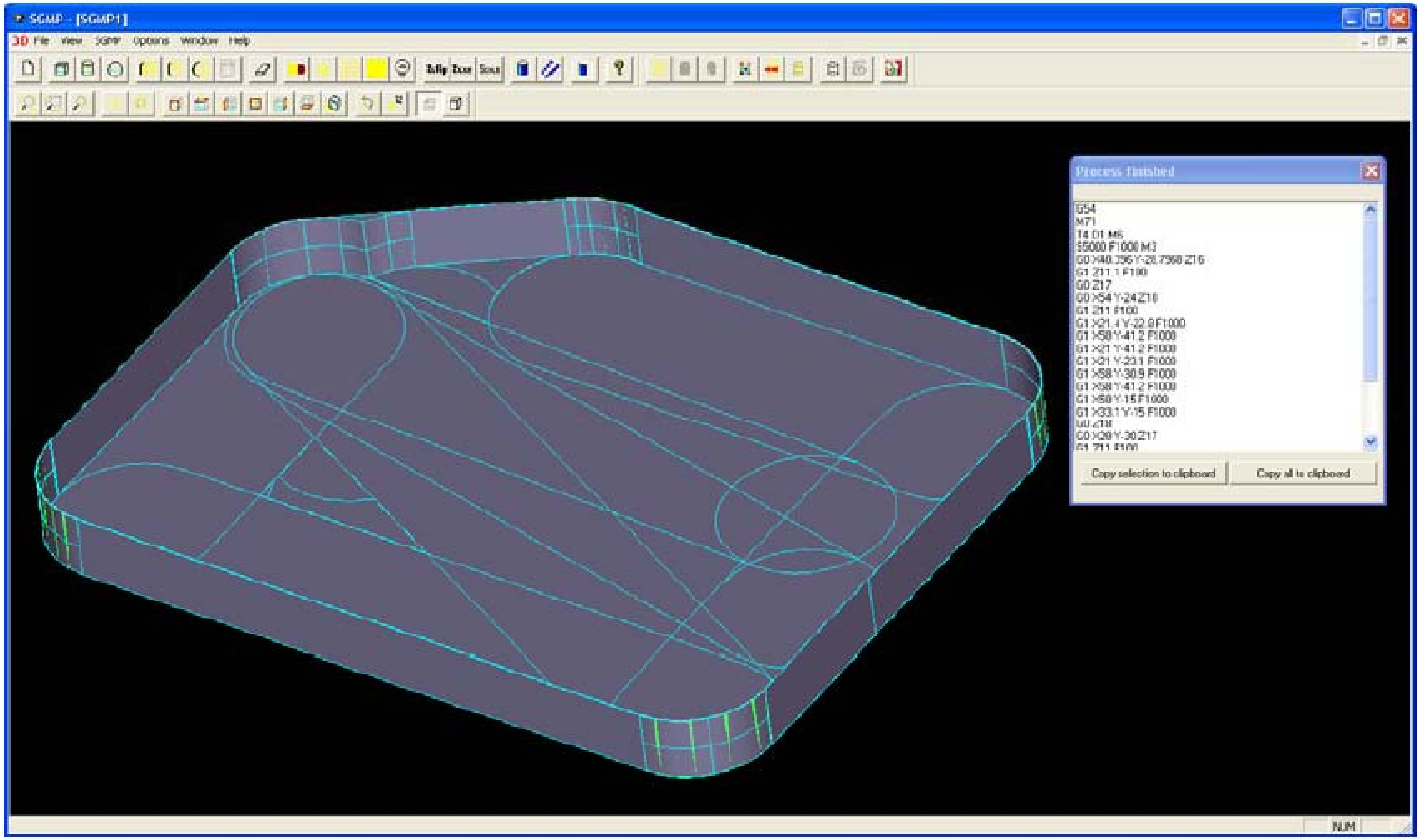
Current: 2.5458 (maximum)



Duarte J P, 2005, "A discursive grammar for customizing mass housing: the case of Siza's houses at Malagueira" *Automation in Construction* ***14* *265-275***

SGMP

Ertelt & Shea 2009


SGMP - [SGMP1]
3D File View SGMP Options Window Help
Process finished
Copy selection to clipboard
Copy all to clipboard
NUM

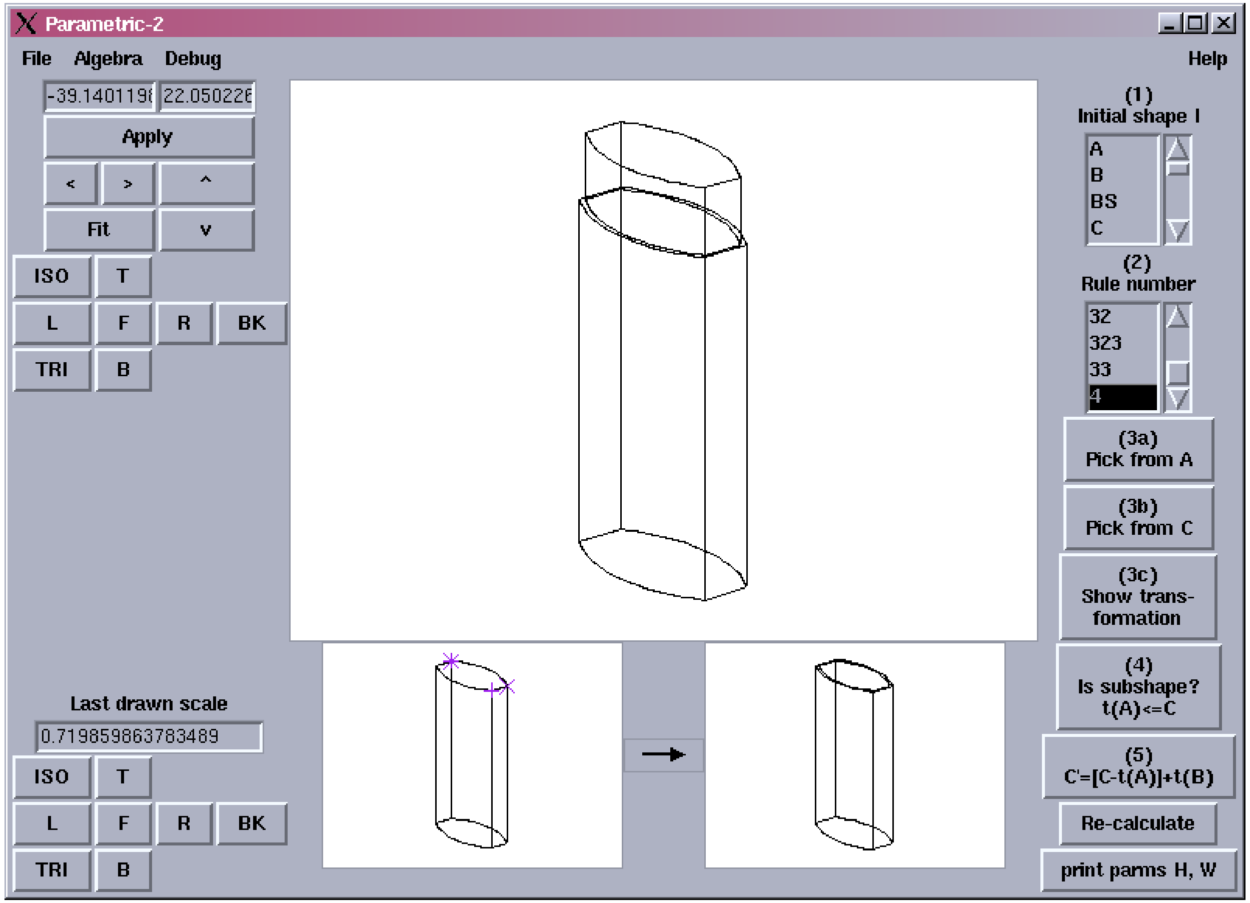
```
G54
M71
T4 D1 M6
S5000 F1000 M3
G0 X40.396 Y-28.7368 Z16
G1 Z11.1 F100
G0 Z17
G0 X54 Y-24 Z16
G1 Z11 F100
G1 X21.4 Y-22.9 F1000
G1 X58 Y-41.2 F1000
G1 X21 Y-41.2 F1000
G1 X21 Y-23.1 F1000
G1 X58 Y-30.9 F1000
G1 X58 Y-41.2 F1000
G1 X50 Y-15 F1000
G1 X33.1 Y-15 F1000
G0 Z18
G0 X20 Y-30 Z17
G1 Z11 F100
```

Ertelt C, Shea K, 2009 "Application of shape grammars to planning for CNC machining", in *Proceedings of the ASME 2009 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE*

Recent general interpreters

3D interpreter

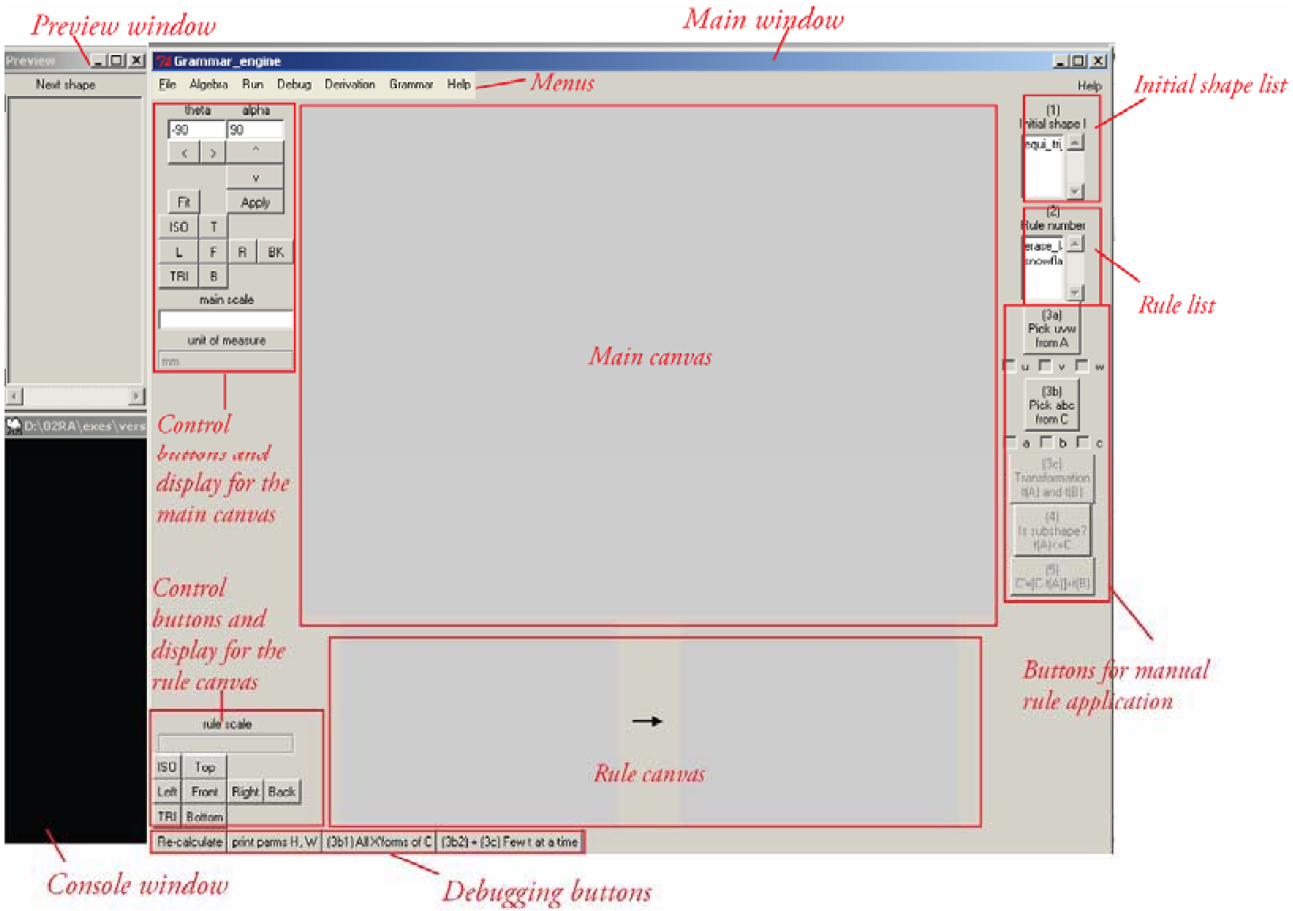
Chau 2002



Chau H H, Chen X, McKay A, de Pennington A, 2004, “Evaluation of a 3D shape grammar implementation” in *Design Computing and Cognition '04: Proceedings of the First International Conference on Design Computing and Cognition* Ed J S Gero (Kluwer, Dordrecht) 357-376

SG development system

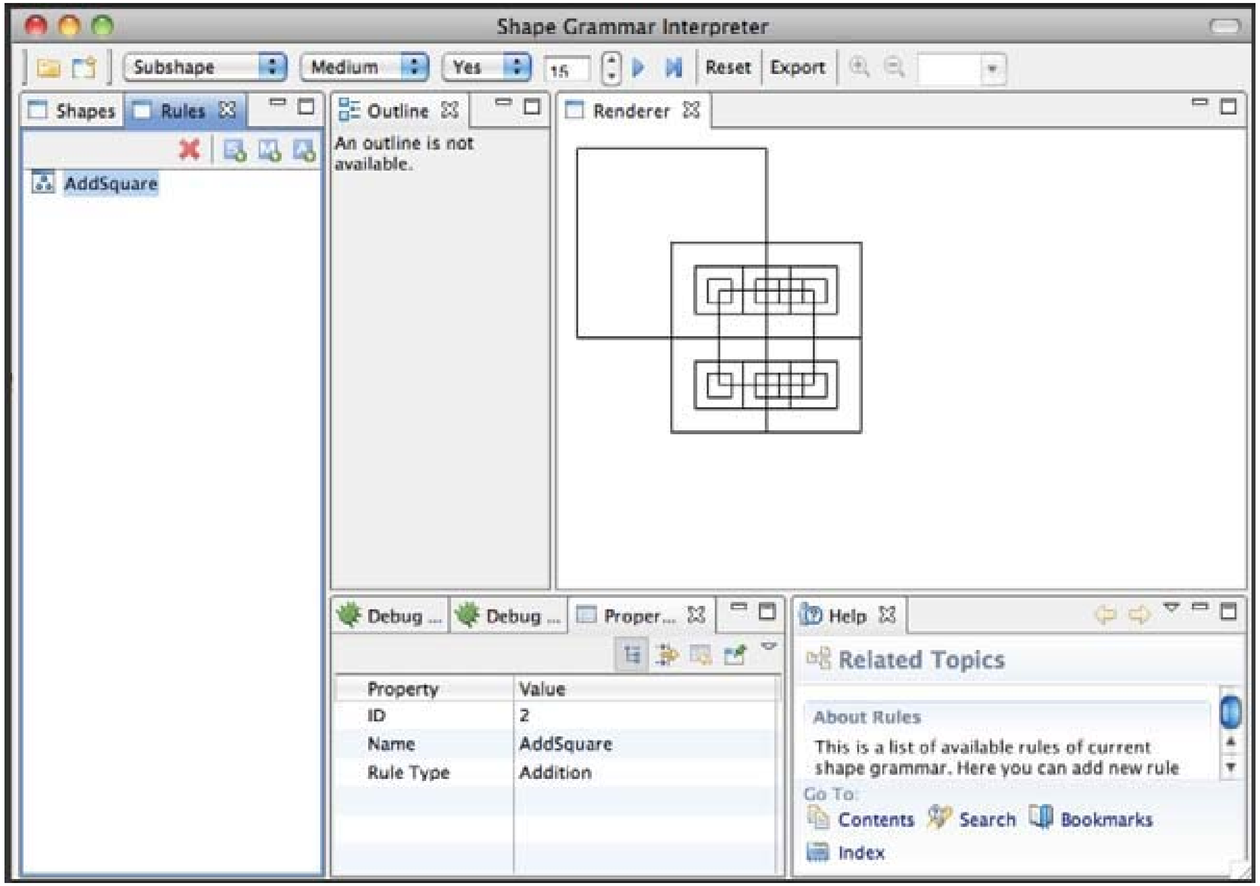
Li et al. 2010



Li, Andrew I-K, Chau H H, Chen L, Wang Y, 2009, "A Prototype System for developing two- and Three-Dimensional Shape Grammars", in Proceedings of the 14th International Conference on Computer Aided Architectural Design Research in Asia (CAADRIA, Yunlin, Taiwan) 717-726

SGI (2)

Trescak et al. 2009



An outline is not available.

Property	Value
ID	2
Name	AddSquare
Rule Type	Addition

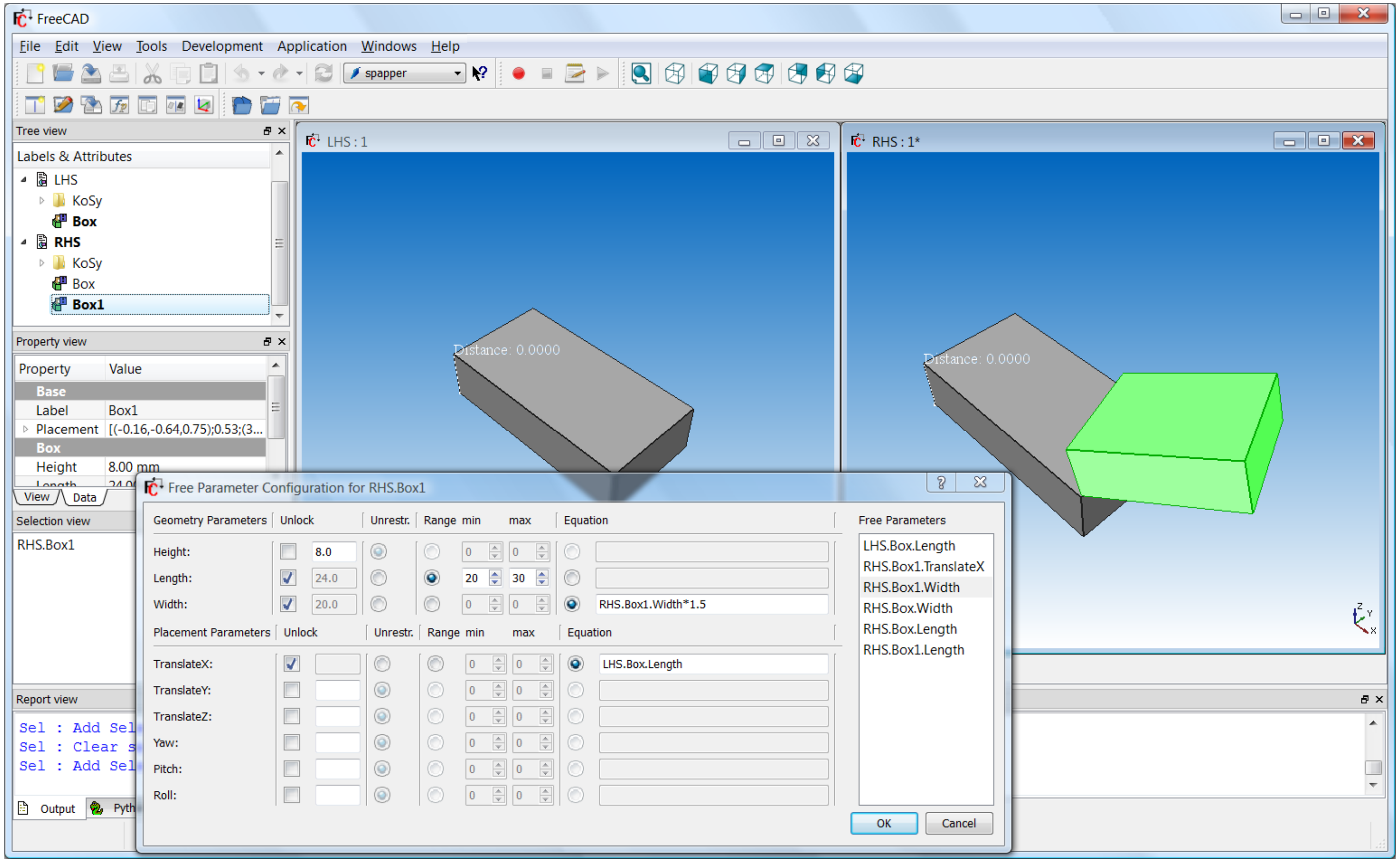
About Rules

This is a list of available rules of current shape grammar. Here you can add new rule

http://sourceforge.net/projects/sginterpreter

Interactive 3D Spatial Grammar System

Hoisl & Shea 2010



Labels & Attributes
- LHS
  - KoSy
  - **Box**
- **RHS**
  - KoSy
  - Box
  - **Box1**

Property view

Property	Value
Base	
Label	Box1
Placement	[(-0.16,-0.64,0.75);0.53;(3...
Box	
Height	8.00 mm
Length	24.0

Selection view

RHS.Box1

Report view

```
Sel : Add Sel
Sel : Clear s
Sel : Add Sel
```

Free Parameter Configuration for RHS.Box1

Geometry Parameters	Unlock		Unrestr.	Range	min	max	Equation	
Height:	☐	8.0	●	○	0	0	○	
Length:	☑	24.0	○	●	20	30	○	
Width:	☑	20.0	○	○	0	0	●	RHS.Box1.Width*1.5
Placement Parameters	**Unlock**		**Unrestr.**	**Range**	**min**	**max**	**Equation**	
TranslateX:	☑		○	○	0	0	●	LHS.Box.Length
TranslateY:	☐		●	○	0	0	○	
TranslateZ:	☐		●	○	0	0	○	
Yaw:	☐		●	○	0	0	○	
Pitch:	☐		●	○	0	0	○	
Roll:	☐		●	○	0	0	○	

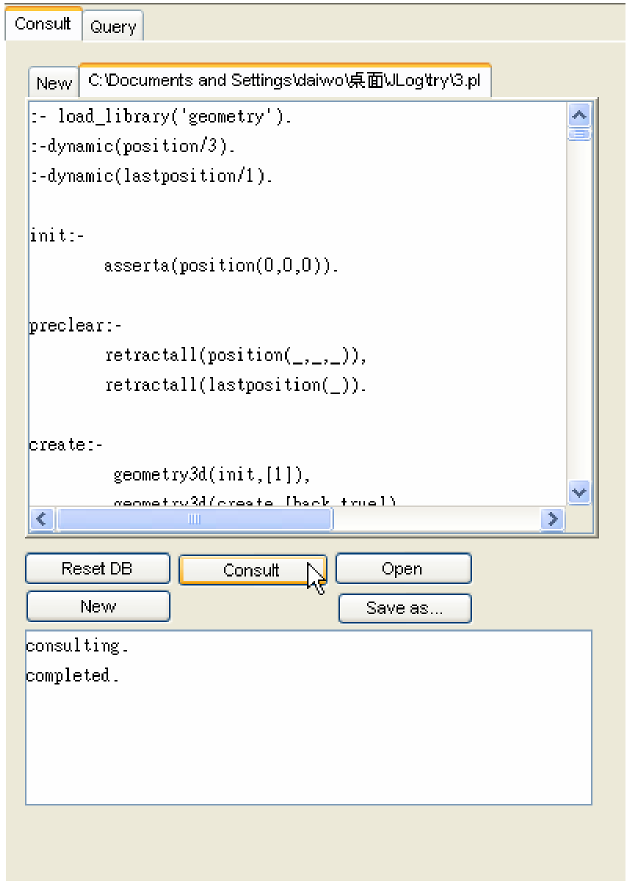
Free Parameters
- LHS.Box.Length
- RHS.Box1.TranslateX
- RHS.Box1.Width
- RHS.Box.Width
- RHS.Box.Length
- RHS.Box1.Length

OK Cancel

http://sourceforge.net/projects/spapper

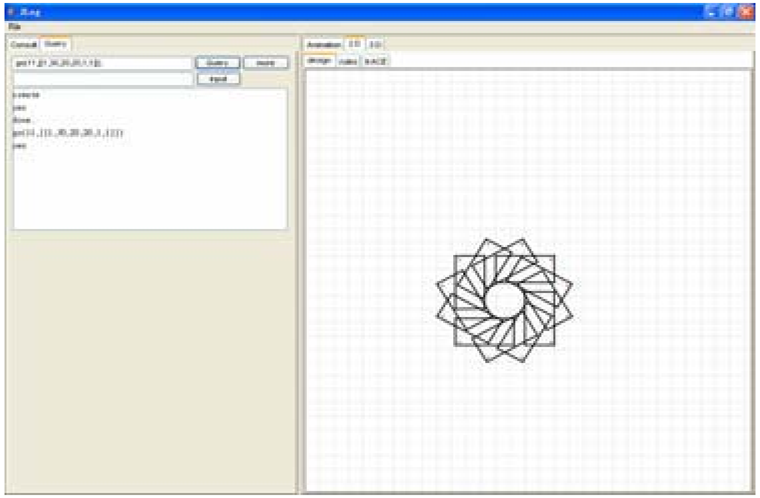
Shape Designer (v2)

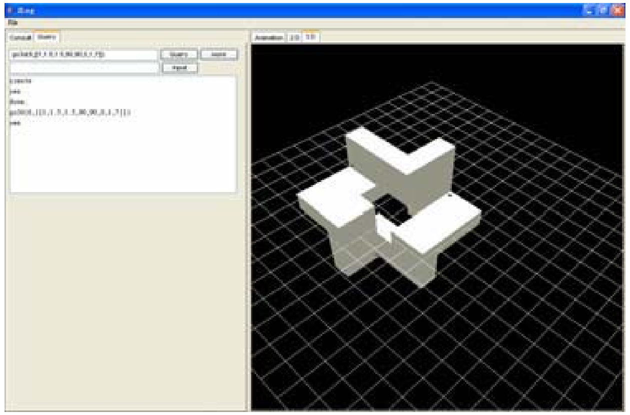
Wong et al. 2004-5



```
:- load_library('geometry').
:-dynamic(position/3).
:-dynamic(lastposition/1).

init:-
        asserta(position(0,0,0)).

preclear:-
        retractall(position(_,_,_)),
        retractall(lastposition(_)).

create:-
         geometry3d(init,[1]),
         geometry3d(create,[back,true]),
```

```
consulting.
completed.
```





Wong W-K, Wan-Ying Wang W-Y, Bo-Yu Chen B-Y, Sheng-Kai Yin S-K, 2005, "Designing 2D and 3D Shape Grammars with Logic Programming" in the *10th Conference on Artificial Intelligence and Applications*, Taiwan

In conclusion…

- We still have a long way to go to make an impact on industry methods using grammar based approaches

- Areas with a lot of activity; maturity?
  - Representations
    - Including extensions, e.g. curves, parametrics, non-geometric attributes
  - Interfaces

- Promising areas
  - New methods of interaction
  - Integration w/design & production processes

Demo time!