

COMP9444 Neural Networks and Deep Learning

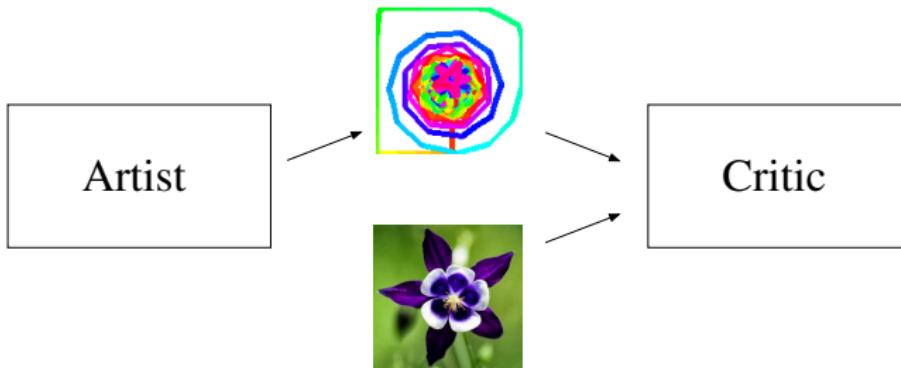
16: Evolutionary Art

Alan Blair, UNSW, 2017-18



Artist-Critic Co-Evolution

Generated Images



Real Images

- ▶ Critic is rewarded for distinguishing real images from those generated by the artist.
- ▶ Artist is rewarded for fooling the critic into thinking that generated images are real.



Co-Evolution Paradigms

Artist	Critic	Method	Reference
Biomorph	Human	Blind Watchmaker	(Dawkins, 1986)
GP	Human	Blind Watchmaker	(Sims, 1991)
CPPN	Human	PicBreeder	(Secretan, 2011)
CA	Human	EvoEco	(Kowaliw, 2012)
GP	SOM	Artificial Creativity	(Saunders, 2001)
Photo	NN	Computational Aesthetics	(Datta, 2006)
GP	NN	Computational Aesthetics	(Machado, 2008)
Agents	NN	Evolutionary Art	(Greenfield, 2009)
GP	NN	Aesthetic Learning	(Li & Hu, 2010)
HERCL	HERCL	Co-Evolving Line Drawings	(Vickers, 2017)
HERCL	DCNN	HERCL Function/CNN	(Soderlund)
DCNN	DCNN	Generative Adversarial Nets	(Goodfellow, 2014)
DCNN	DCNN	Plug & Play Generative Nets	(Nguyen, 2016)



PicBreeder (*Secretan, 2011*)



- ▶ Artist = Convolutional Pattern Producing Neural Network (CPPN)
 - ▶ Critic = Human
 - ▶ interactive Web site (picbreeder.org) where you can choose existing individual and use it for further breeding
-
- ▶ Blind Watchmaker paradigm is cool, but it may require a lot of work from the Human
 - ▶ Can the Human be replaced by an automated Critic?

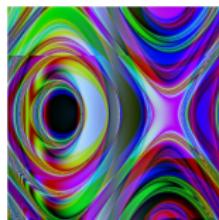
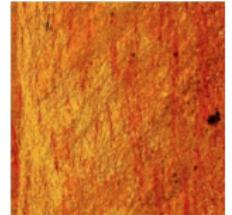
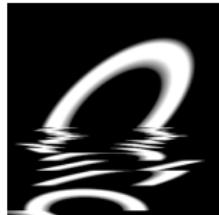
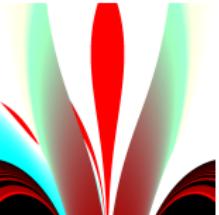


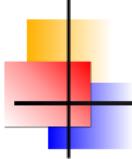
Evolutionary Art

- ▶ Artist = Genetic Program (GP or HERCL)
 - ▶ artist used as a function to compute R,G,B values for each pixel location x, y
 - ▶ alternatively, artist issues a series of drawing instructions
- ▶ Critic = GP (evolution) or Neural Network (backpropagation)
- ▶ Critic is presented with “real” images from a training set, and “fake” images generated by the Artist
- ▶ Critic is trained to produce output close to 1 for real images and close to 0 for generated images (or vice-versa)
- ▶ inputs to Critic
 - ▶ small number of statistical features extracted from the image
 - ▶ more recently, raw image, fed to DCNN

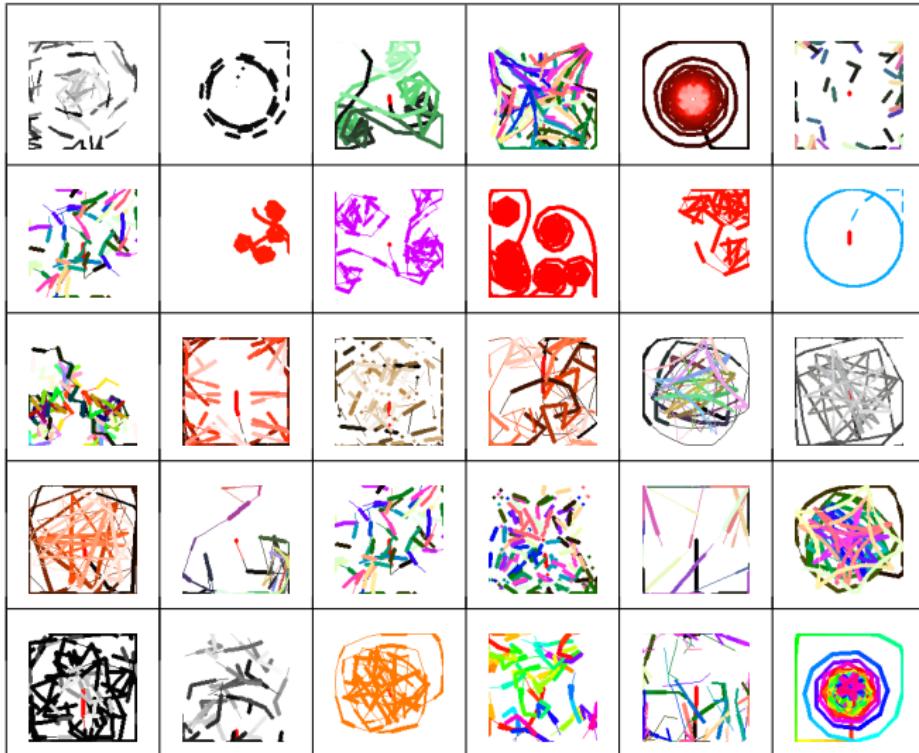


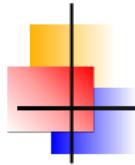
Image Generating Paradigms

			
Biomorph	GP	Picbreeder	CA
			
HERCL(draw)	HERCL(func)	HERCL(func)	GAN



Artist-Critic Coevolution





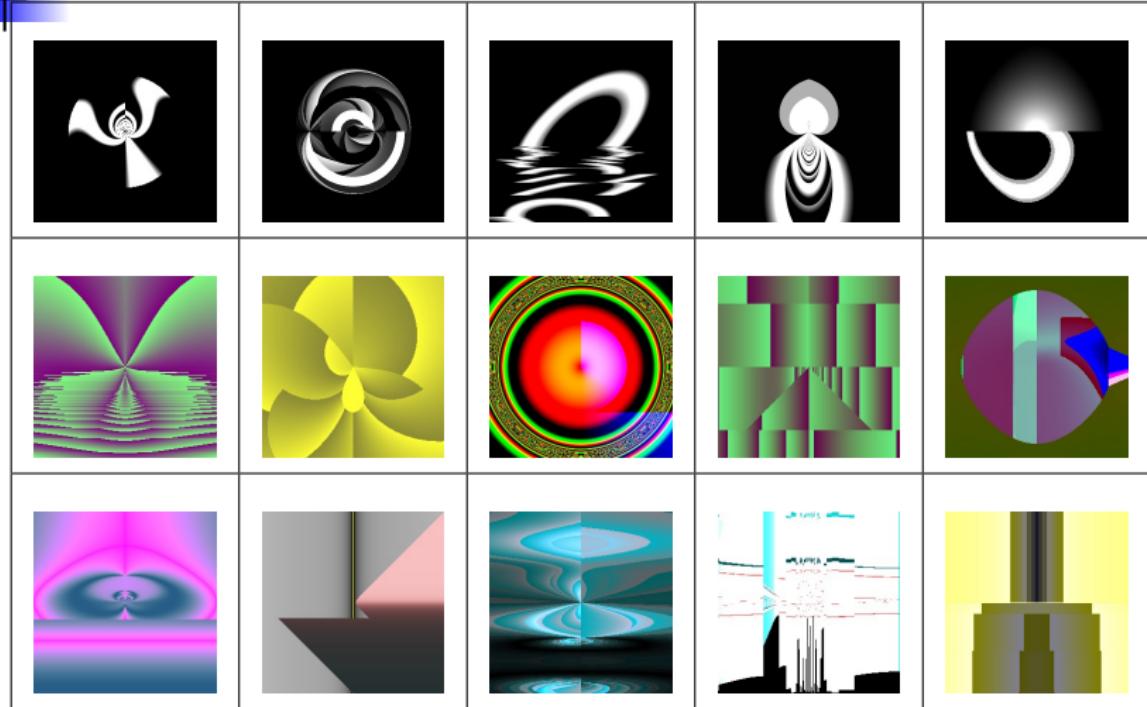
Line Drawing Commands

0	TOGGLE		lift pen on/off page
1	MOVE	x	move pen forward by x pixels ($0 \leq x \leq 15$)
2	TURN	x	turn x degrees clockwise
3	SIZE	p	set pen radius to p pixels ($1 \leq p \leq 4$)
4	COLOUR	v	set greyscale value [greyscale mode]
	COLOUR	$l \ h \ s$	set colour in HSV colour space [colour mode]

- ▶ the output from the HERCL program is interpreted as a series of line drawing commands
- ▶ Critic is also a HERCL program, based on 20 statistical features extracted from the image



Computational Creativity



- ▶ Artist = HERCL program as a function from x,y to R,G,B
- ▶ Critic = Deep Convolutional Neural Network (LeNet)



- ▶ combines elements from Linear GP and Stack-based GP.
 - ▶ programs have access to a stack, registers and memory.
 - ▶ each instruction is a single character, possibly preceded by a numerical (or dot) argument.

Input and Output

- i fetch INPUT to input buffer
- s SCAN item from input buffer to stack
- w WRITE item from stack to output buffer
- o flush OUTPUT buffer

Stack Manipulation and Arithmetic

- # PUSH new item to stack $\mapsto \dots x$
- ! POP top item from stack $x \mapsto \dots$
- c COPY top item on stack $x \mapsto \dots x, x$
- x SWAP top two items $\dots y, x \mapsto \dots x, y$
- y ROTATE top three items $z, y, x \mapsto x, z, y$
- NEGATE top item $\dots x \mapsto \dots (-x)$
- + ADD top two items $\dots y, x \mapsto \dots (y + x)$
- * MULTIPLY top two items $\dots y, x \mapsto \dots (y * x)$

Mathematical Functions

- | | | |
|---|----------------------------|--------------------------------------|
| r | RECIPROCAL | $\dots x \rightarrow \dots 1/x$ |
| q | SQUARE ROOT | $\dots x \rightarrow \dots \sqrt{x}$ |
| e | EXPONENTIAL | $\dots x \mapsto \dots e^x$ |
| n | (natural) LOGARITHM | $\dots x \mapsto \dots \log_e(x)$ |
| a | ARCSINE | $\dots x \mapsto \dots \sin^{-1}(x)$ |
| h | TANH | $\dots x \mapsto \dots \tanh(x)$ |
| z | ROUND to nearest integer | |
| ? | push RANDOM value to stack | |

Double-Item Functions

- | | | |
|---|---------------|---|
| % | DIVIDE/MODULO | $\dots y, x \mapsto \dots (y/x), (y \bmod x)$ |
|---|---------------|---|

- | | | |
|---|----------------|--|
| t | TRIG functions | $\dots \theta, r \mapsto \dots r \sin \theta, r \cos \theta$ |
|---|----------------|--|

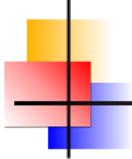
- | | | |
|---|--------------|---|
| p | POLAR coords | $\dots y, x \mapsto \dots \text{atan2}(y, x), \sqrt{x^2 + y^2}$ |
|---|--------------|---|

Registers and Memory

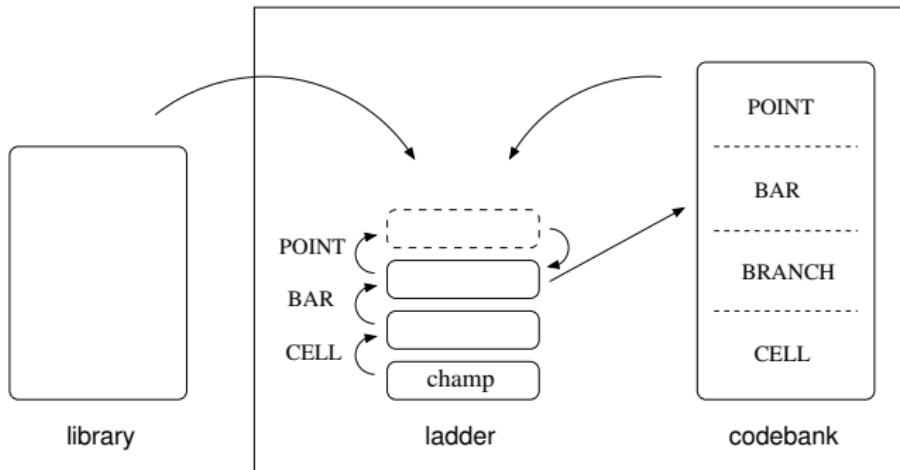
- < GET value from register
 - > PUT value into register
 - ^ INCREMENT register
 - v DECREMENT register
 - { LOAD from memory location
 - }
- STORE to memory location

Jump, Test, Branch and Logic

- j JUMP to specified cell (subroutine)
- | BAR line (RETURN on . | HALT on 8|)
- = register is EQUAL to top of stack
- g register is GREATER than top of stack
- :
- : if TRUE, branch FORWARD
- ;
- ; if TRUE, branch BACK
- & logical AND / logical OR ~ logical NOT



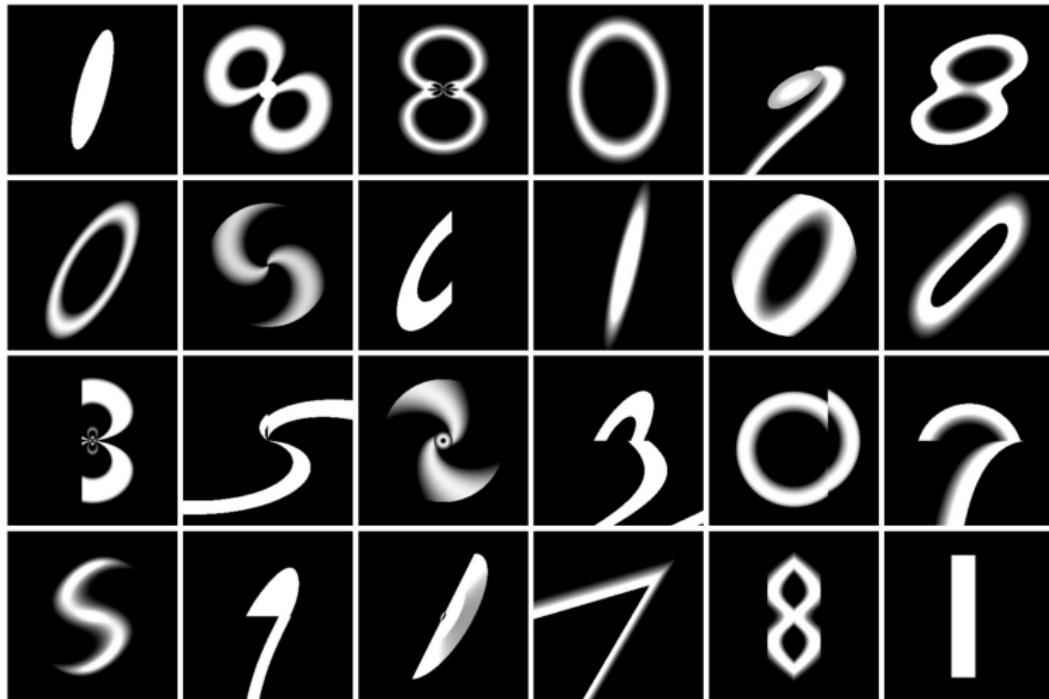
Hierarchical Evolutionary Re-Combination



- ▶ large crossover/mutation can be followed up by smaller ones.
- ▶ if top agent becomes fitter, it moves down to replace the one below it (which is moved to the codebank).
- ▶ if top agent exceeds max number of offspring, it is removed.
- ▶ good for co-evolution because it keeps the number of competing agents small while preserving diversity.

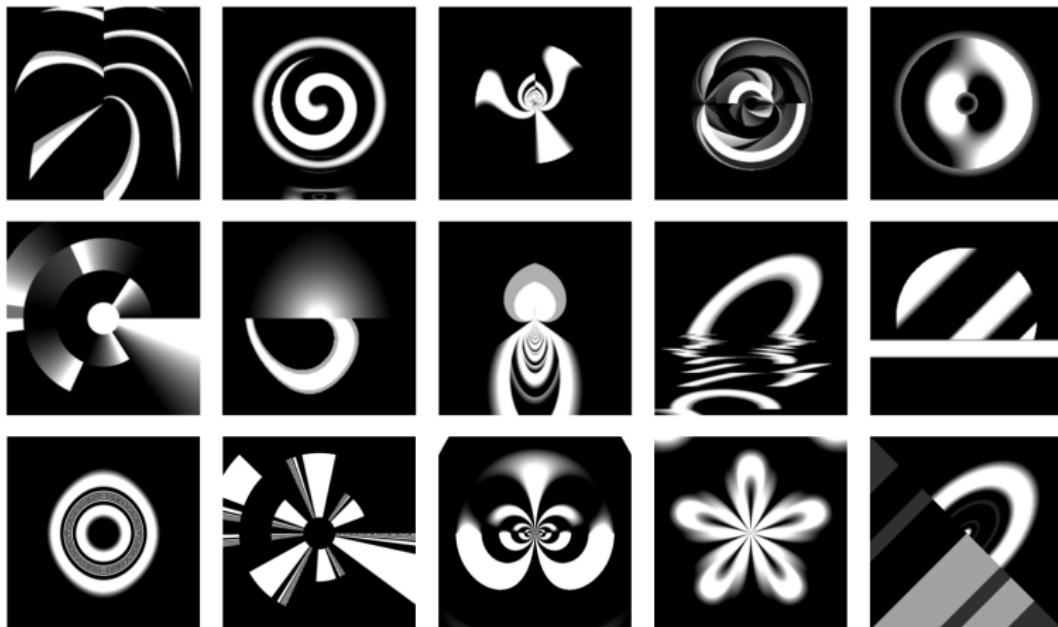


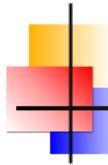
Images trained against MNIST





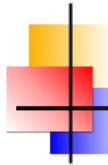
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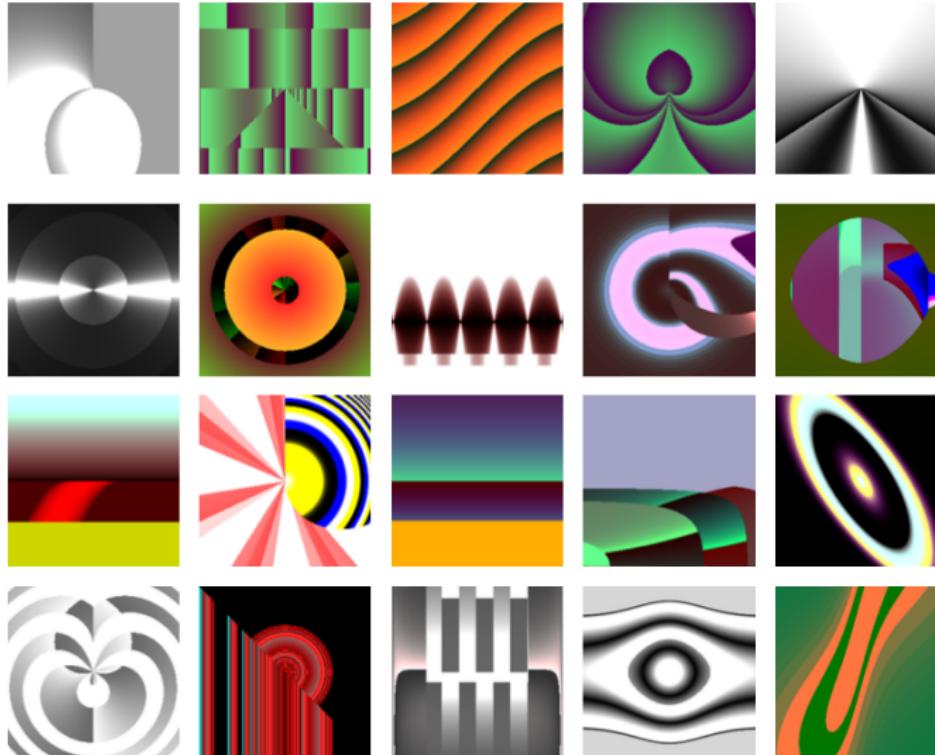


Images trained against CIFAR-10



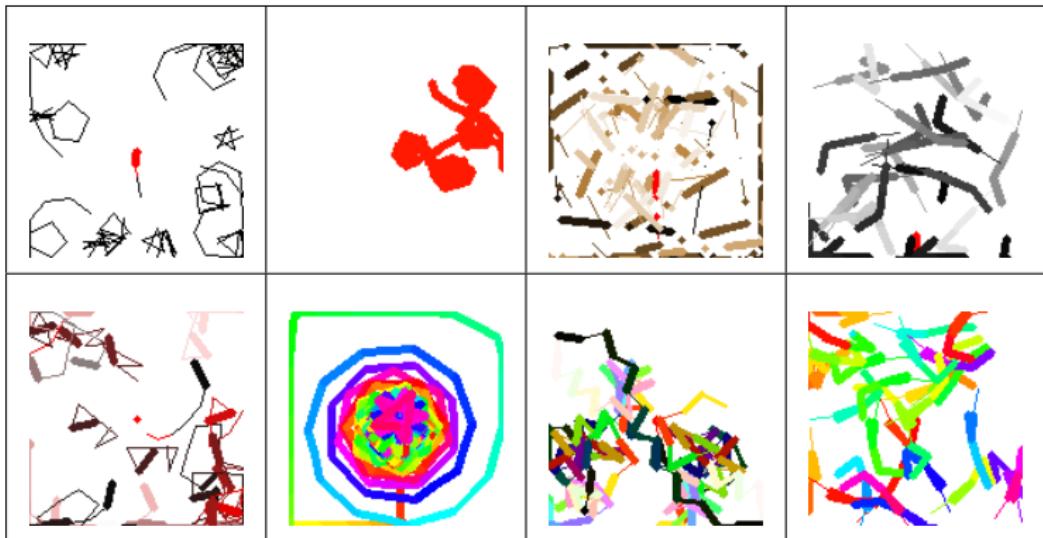


Images trained against CIFAR-10



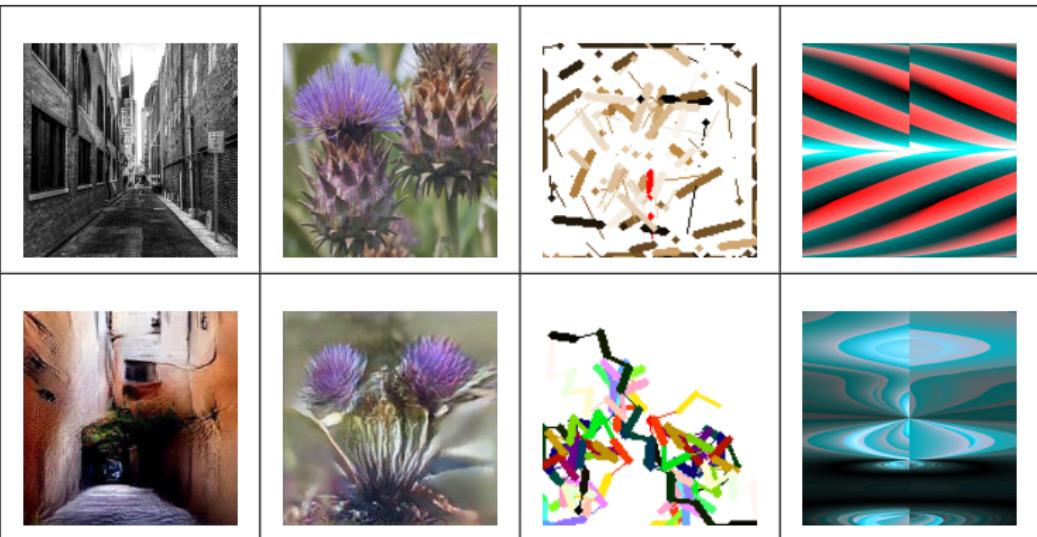


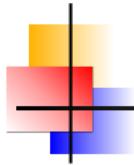
Self-Similarity, Low Complexity Art



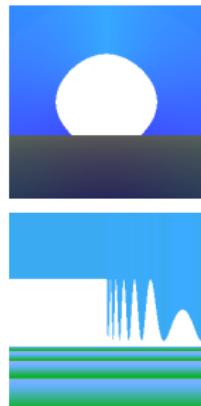
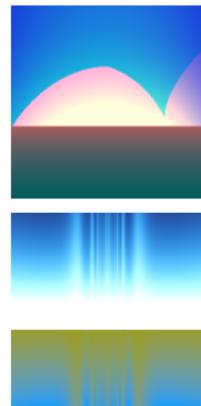
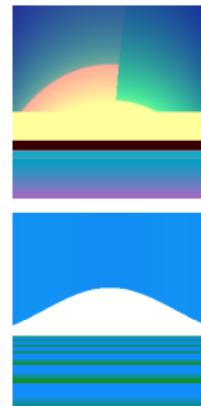
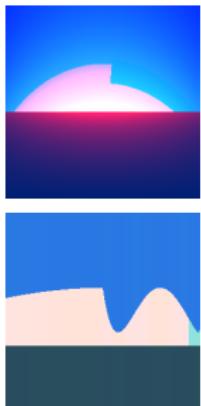
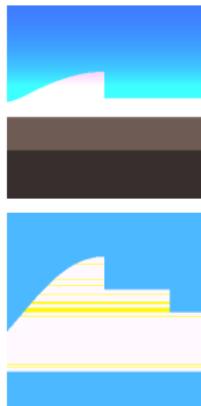


Self-Similarity



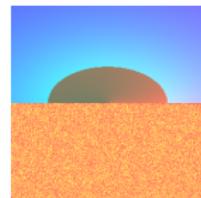
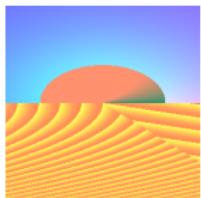
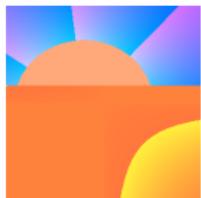
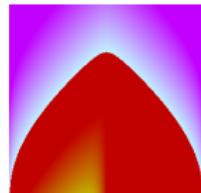
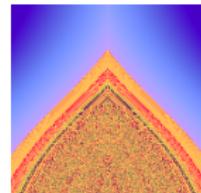
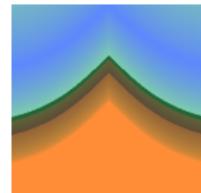
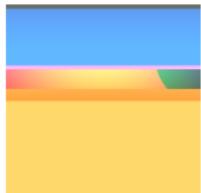


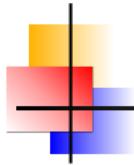
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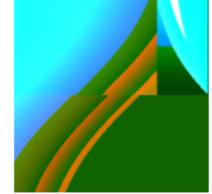
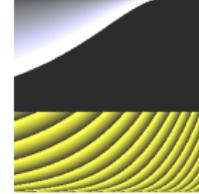
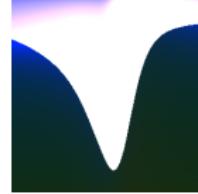
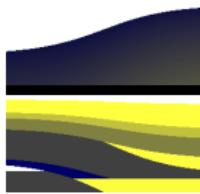
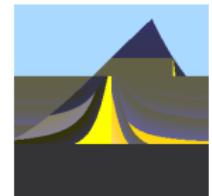
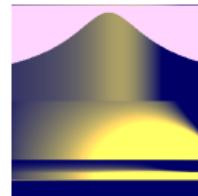
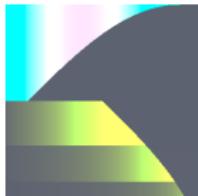


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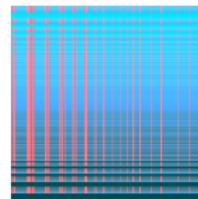
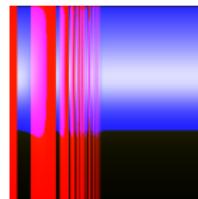
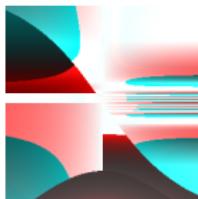
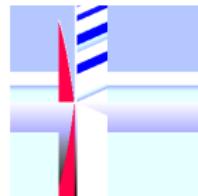
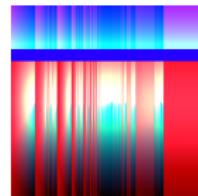
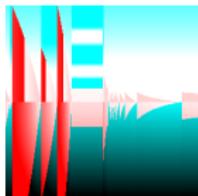
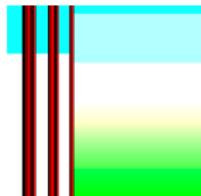


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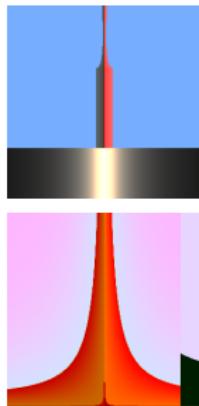
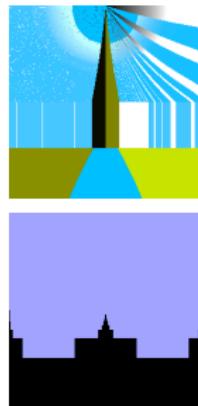
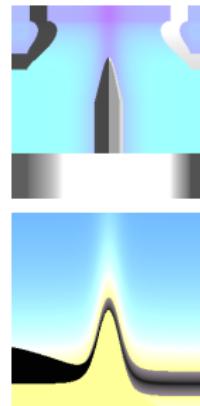
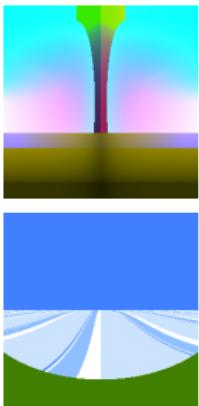
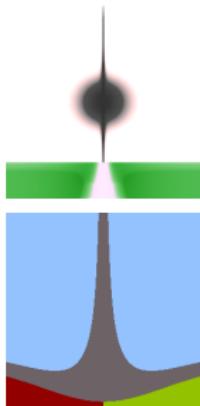


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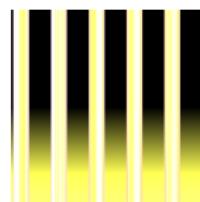
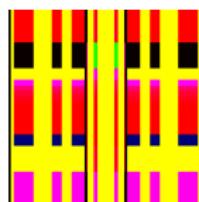
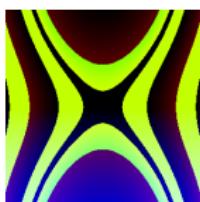
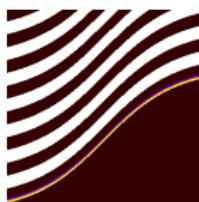
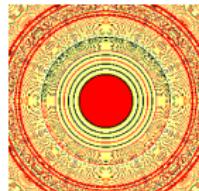
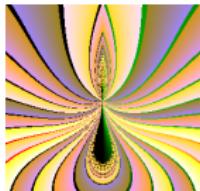


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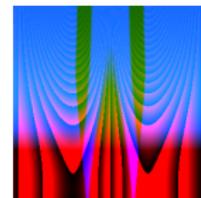
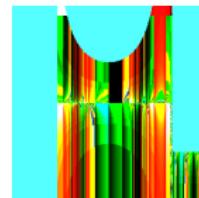
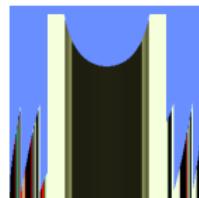
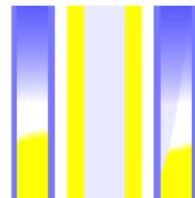
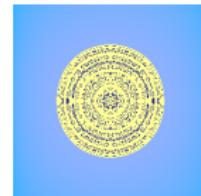
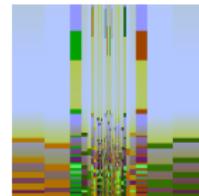
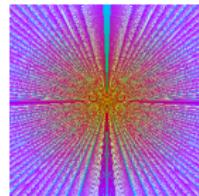
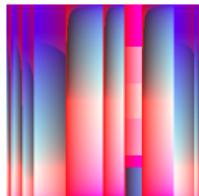
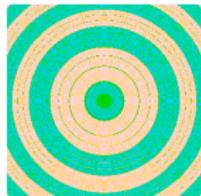


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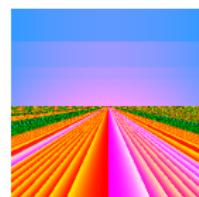
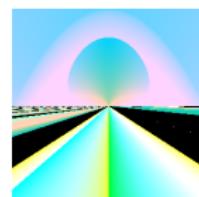
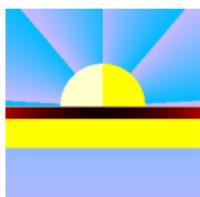
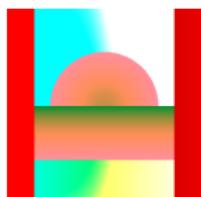
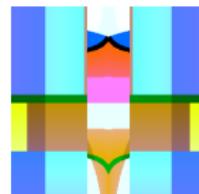
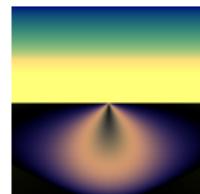
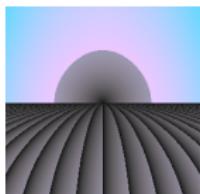
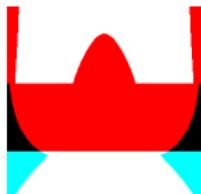


Which Landmark?



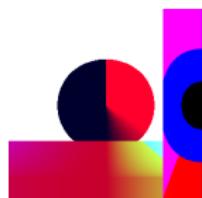
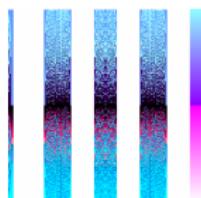
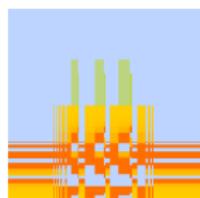
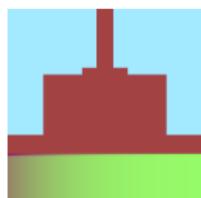
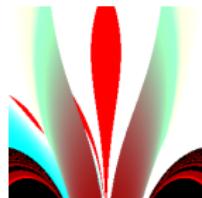
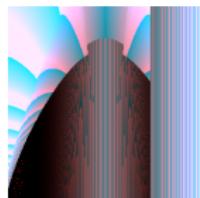


Which Landmark?



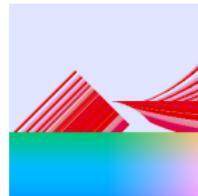
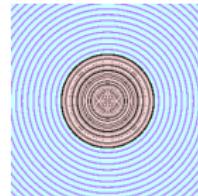
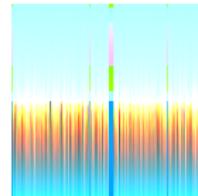
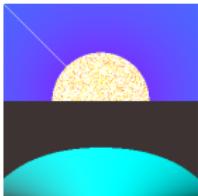
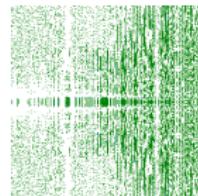
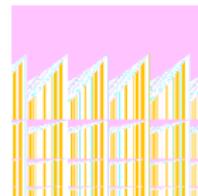
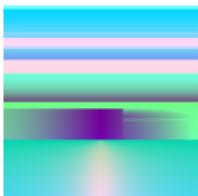


Which Landmark?





Which Landmark?



Questions ?