

Adversarial Evolution and Deep Learning – How does an Artist Play with our Visual System?

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Abstract

We create artworks using adversarial coevolution between a genetic program (HERCL) generator and a deep convolutional neural network (LeNet) critic. The resulting artificially intelligent artist (Hercule LeNet) aims to produce images of low algorithmic complexity which nevertheless resemble a set of real photographs well enough to fool an adversarially trained deep learning critic modeled on the human visual system.

Artist Critic Coevolution

Photos of Landmarks



(public domain) (c) Bernard Gagnon (a) Opera House (b) Eiffel Tower







(c) Mister No (c) Hans Peter Schaefer (c) Allard Schmidt © DannyBoy7783 (public domain) (i) Angel Oak (j) Grand Canal (g) Notre Dame (f) Machu Picchu (h) Taj Mahal

Adversarial Training Paradigm

- ▶ in each round, LeNet critic is trained to assign low cost to "real" images and high cost to images in the gallery
- ► HERCL artist is evolved to produce a new image to which the current critic will assign as low a cost as possible
- ▶ each round adds one new image to the gallery
- ▶ after completion, human selects best images from gallery

Hierarchical Evolutionary **Re-Combination**



HERCL Commands

Input and Output

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

Stack Manipulation and Arithmetic

PUSH new item to stack \dots \mapsto \dots x





Instead of a population, HERCL uses a ladder of candidate solutions plus a **codebank** and **library** of potential mates.

- ► top agent on ladder crossed with agent from codebank or library
- ▶ if top agent becomes fitter than lower agent, top agent will move down to replace lower agent (which is sent to codebank)
- ▶ if top agent exceeds maximum number of offspring, it is culled (and sent to codebank)
- \blacktriangleright in this case, library = code for all previous images in gallery

Evolved Code Example

0[!qatcz]

- POP top item from stack $\dots x \mapsto \dots$
- c COPY top item on stack $\dots x \mapsto \dots x, x$
- **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
- $\dots x \to \dots 1/x$ r RECIPROCAL $\dots x \to \dots \sqrt{x}$ q SQUARE ROOT e EXPONENTIAL $\dots x \mapsto \dots e^x$ **n** (natural) LOGARITHM $\dots x \mapsto \dots \log_e(x)$ $\dots x \mapsto \dots \sin^{-1}(x)$ a ARCSINE $\dots x \mapsto \dots \tanh(x)$ h TANH
- **z** ROUND to nearest integer
- ? push RANDOM value to stack

Double-Item Functions

% DIVIDE/MODULO $y, x \mapsto \dots (y/x), (y \mod x)$ t TRIG functions $..\theta, r \mapsto ..r \sin \theta, r \cos \theta$ **p** POLAR coords $.., y, x \mapsto ... \operatorname{atan}^2(y, x), \sqrt{x^2 + y^2}$

Registers and Memory

- < GET value from register > PUT value into register
- (a) [365] (b) [905] $\left(C \right) \left[685 \right]$ (i) [573] (j) [221] Saint Basil's Cathedral (a) [725] (C) [379] (b) [877] (d) [280] (e) [478] Notre Dame de Paris (b) [592] (C) [158] (d) [159] (e) [155] (a) [32] Machu Picchu (g) [295] (a) [574] (h) [408] (d) [735] (e) [725] Taj Mahal

1[capwwwo.]

2[%]

3[is.32#>sg:1j|c>xg:hp2j|+a{>cpa%.4338#p>g~<:0j|xww.88#wo]

Artistic Styles and Analysis

Minimalism and Abstraction:

- ► object is suggested by simple pattern of colors and shapes
- ▶ some components may be distorted, or absent; suprematism Colors and Shading:
- ► CNN can focus on relative rather than absolute color
- ▶ bright colors, fauvism, enhanced contrast, "halo" effect
- ▶ sometimes minimal color, but enhanced shading

Fractals and Texture:

- ► low algorithmic complexity achieved through self-similarity
- ▶ psychedelic and fractal art; similar to M.C. Escher
- ▶ sharp changes in function x, y to R,G,B can create pointillism

Metaphor:

- ► Golden Gate Bridge as scarves hanging on a line ► Saint Basil's Cathedral as flower or colored ribbons

- INCREMENT register
- **v** DECREMENT register LOAD from memory location STORE to memory location
- Jump, Testing, Branching and Logic JUMP to specified cell (subroutine)
- BAR line (RETURN on . | HALT on 8|)
- = check register is EQUAL to top of stack g check register is GREATER than top of stack
- : if TRUE, branch FORWARD
- ; if TRUE, branch BACK
- & logical AND
- logical OR
- ~ logical NOT



► Taj Mahal as kite, bird or totem pole

► Angel Oak Tree as psychedelic insect

► Grand Canal as ship fabricated from raw materials **Repeated Substructures with Variations:**

► creates the impression of having arisen from a natural process

Conclusion

- ► system can produce artworks from famous landmarks
- ▶ art emerges from tradeoff between selective pressure for
- low algorithmic complexity, and imperative to fool the critic
- ► stylistic features recognizable from influential art movements of the 19th and 20th Century