

Deep Learning for Visual Arts

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FACULDADE DE
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UNIVERSIDADE DE
COIMBRA



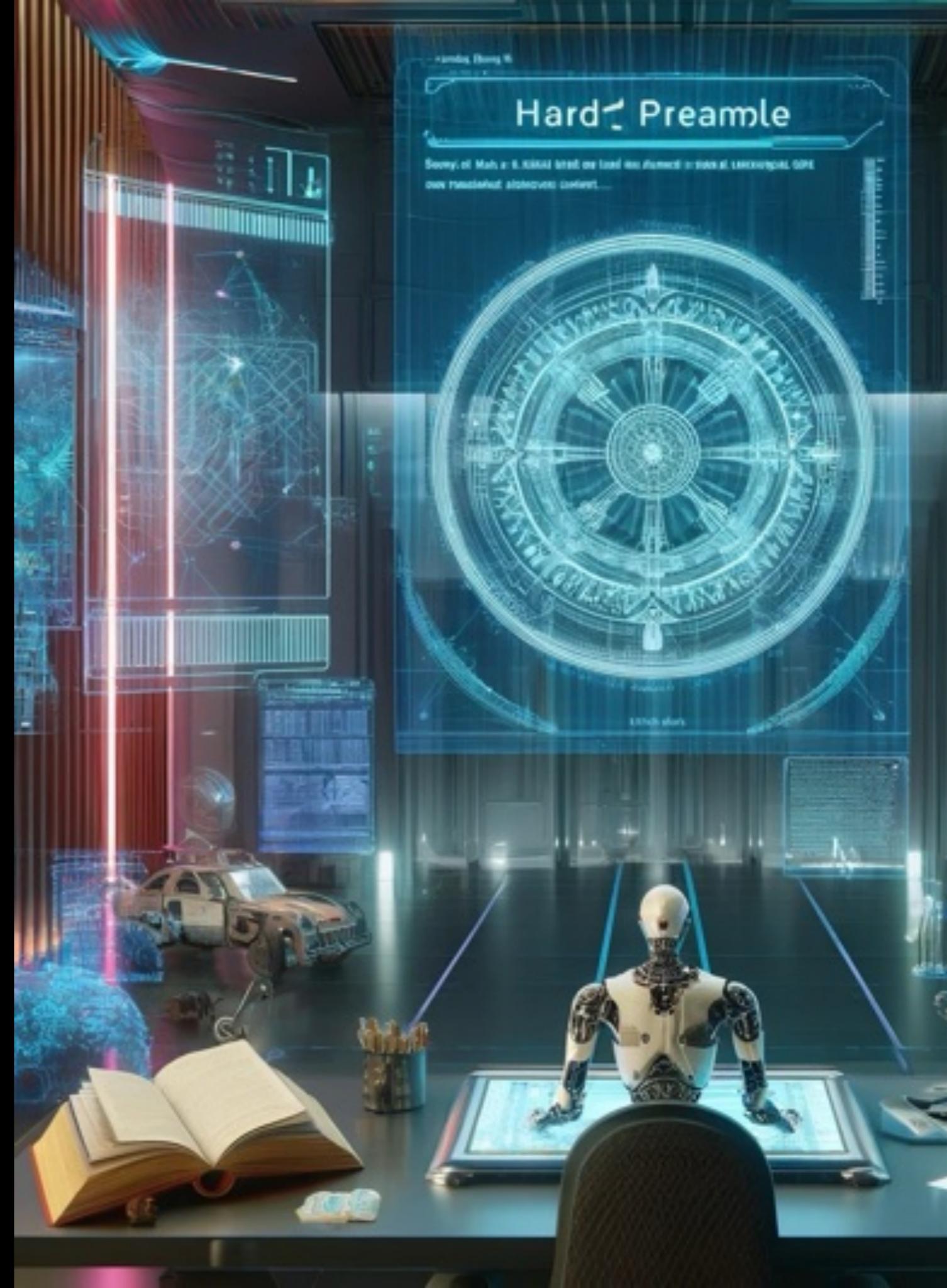
Hard Preamble

Disclaimer?

Not an Artist

Not an Artistic View

Not discussing Art



Hard Preamble

Disclaimer

Informatics

Researcher

Professor



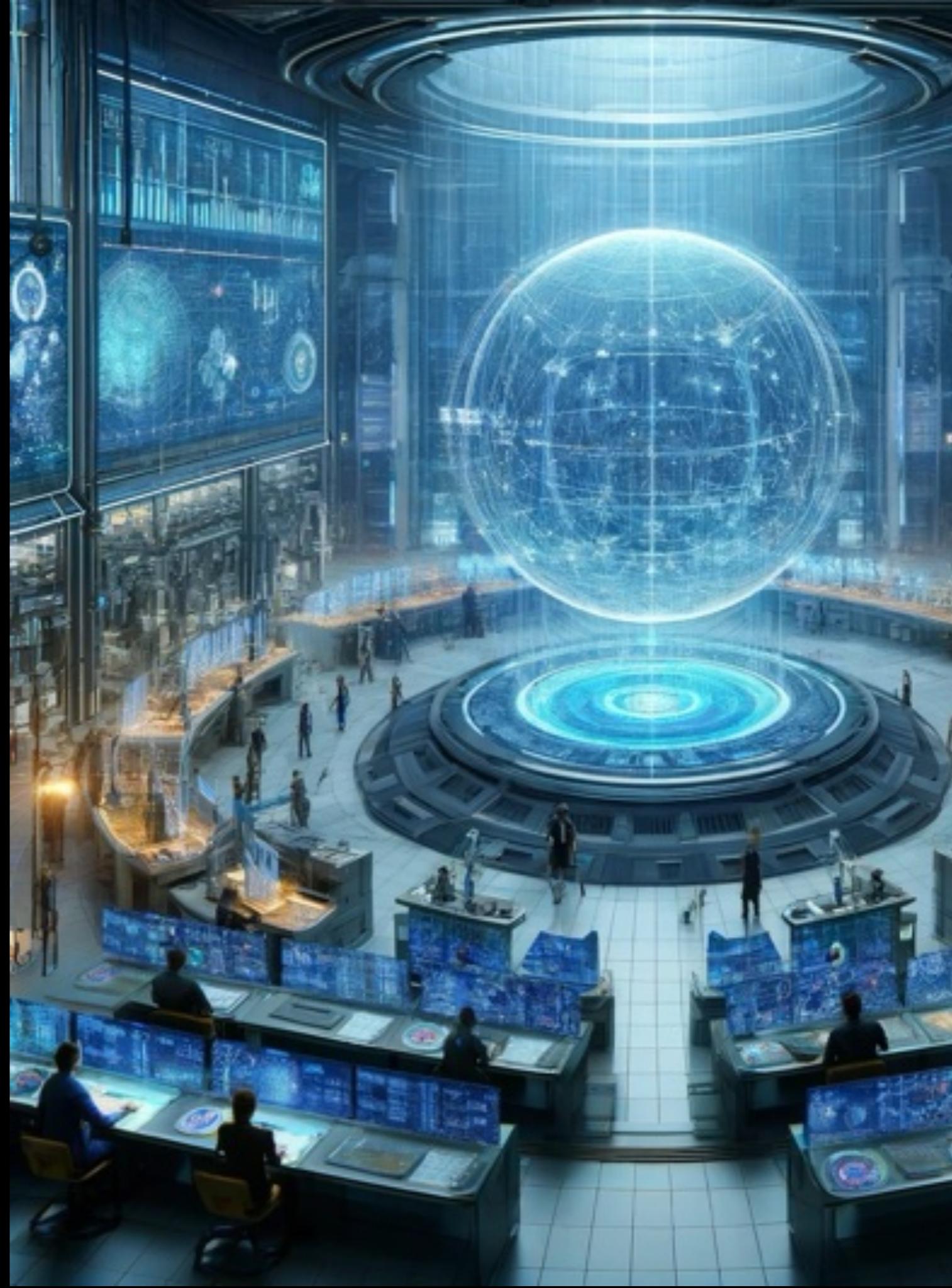
Hard Preamble

Today

Perspective and from
Experience

Concepts and Models

Applied Generative
Image Models (Visual)



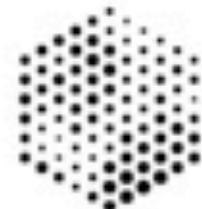
Hard Preamble

Research

Evolutionary
Computation

Machine
Learning

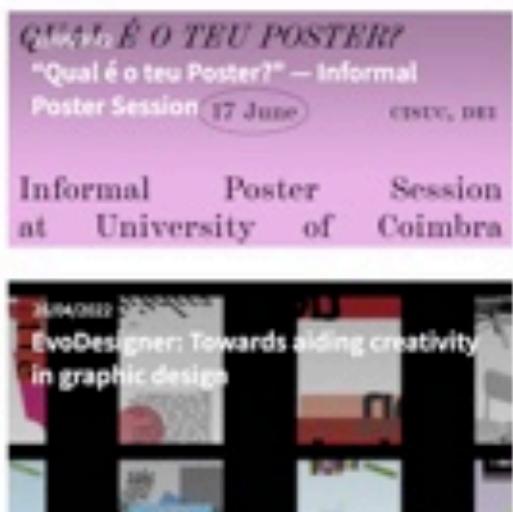
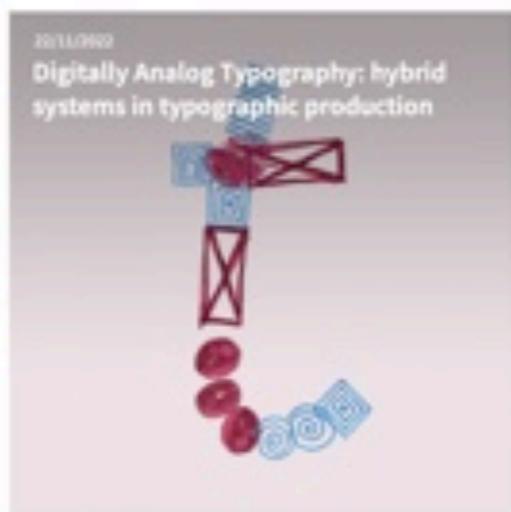
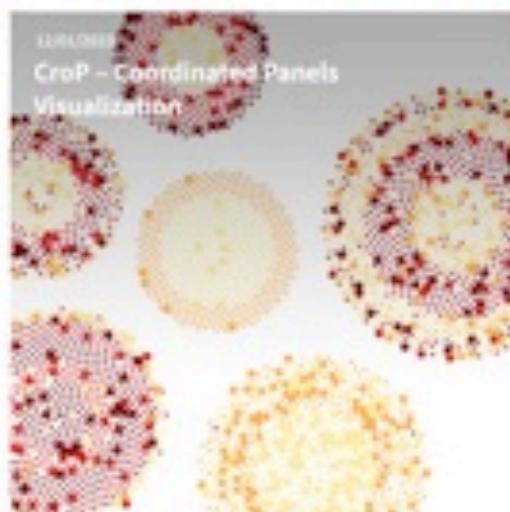
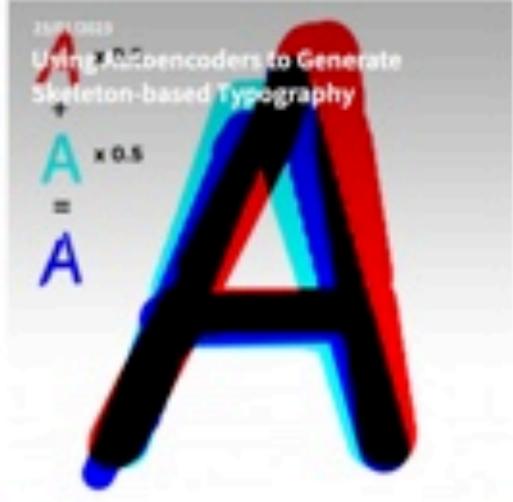
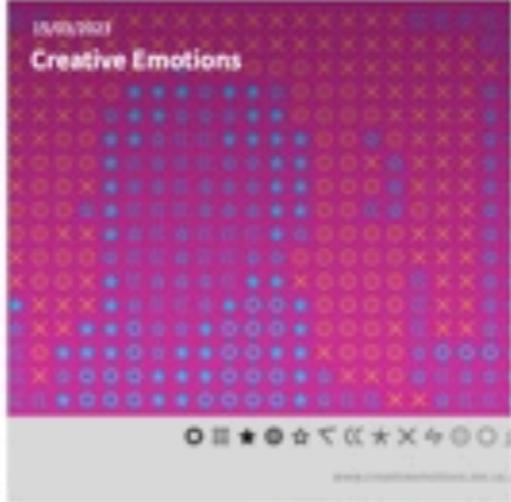
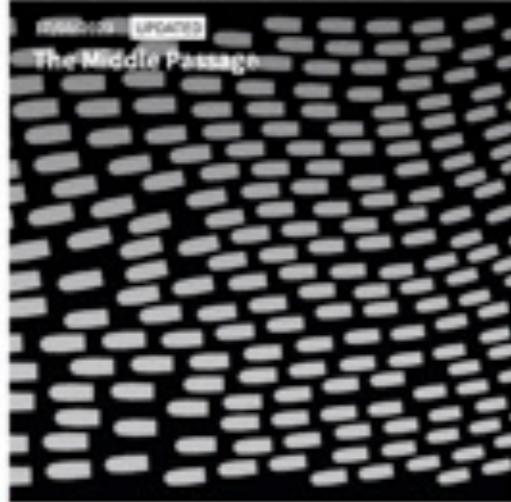
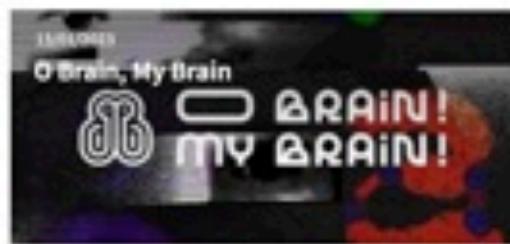




COMPUTATIONAL
DESIGN &
VISUALIZATION
LAB.

About
People
Publications
Projects
News
Snapshots

Write Something

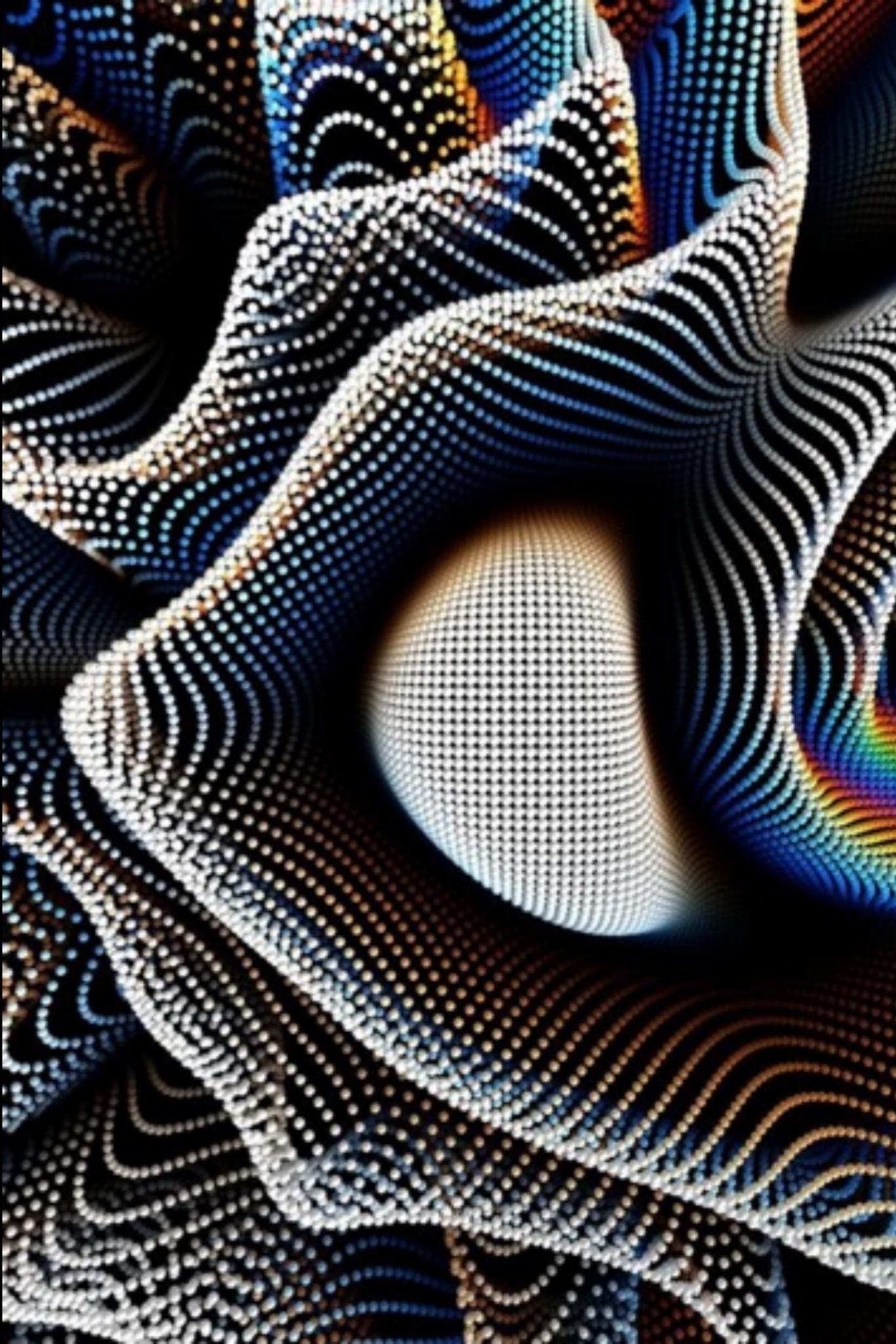


Concepts and Definitions

Generative Model

A General definition

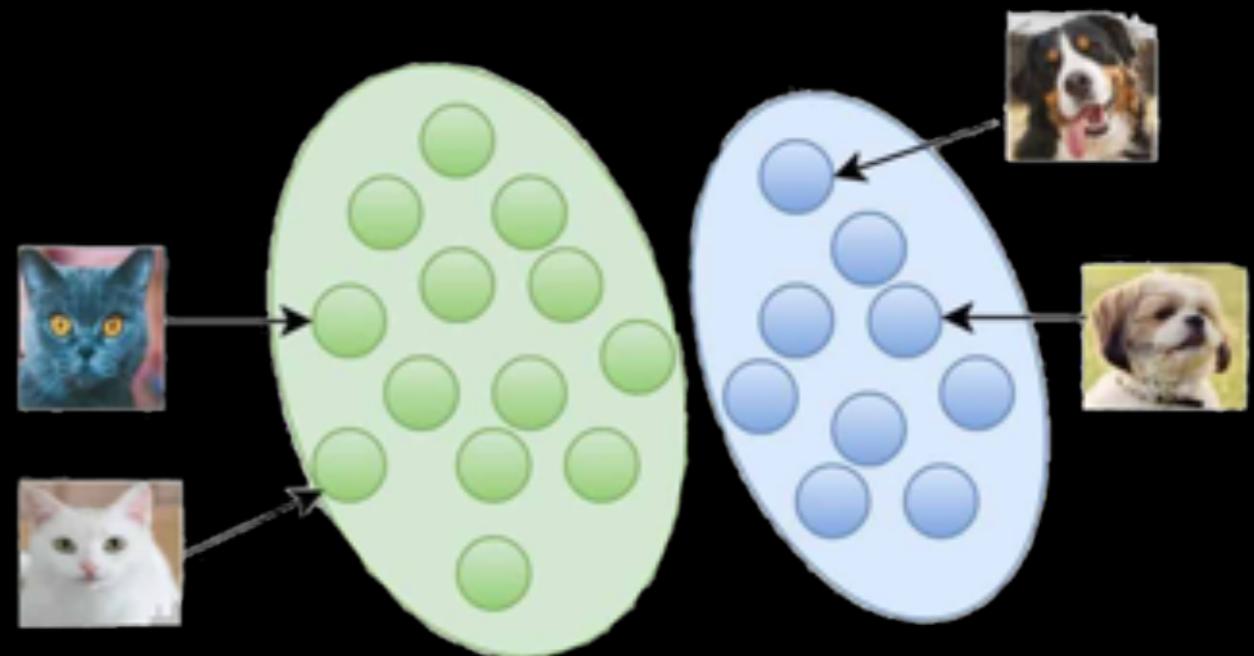
A generative model typically implements an algorithmic process that generates outputs that serve a certain objective or concept.



Generative Model

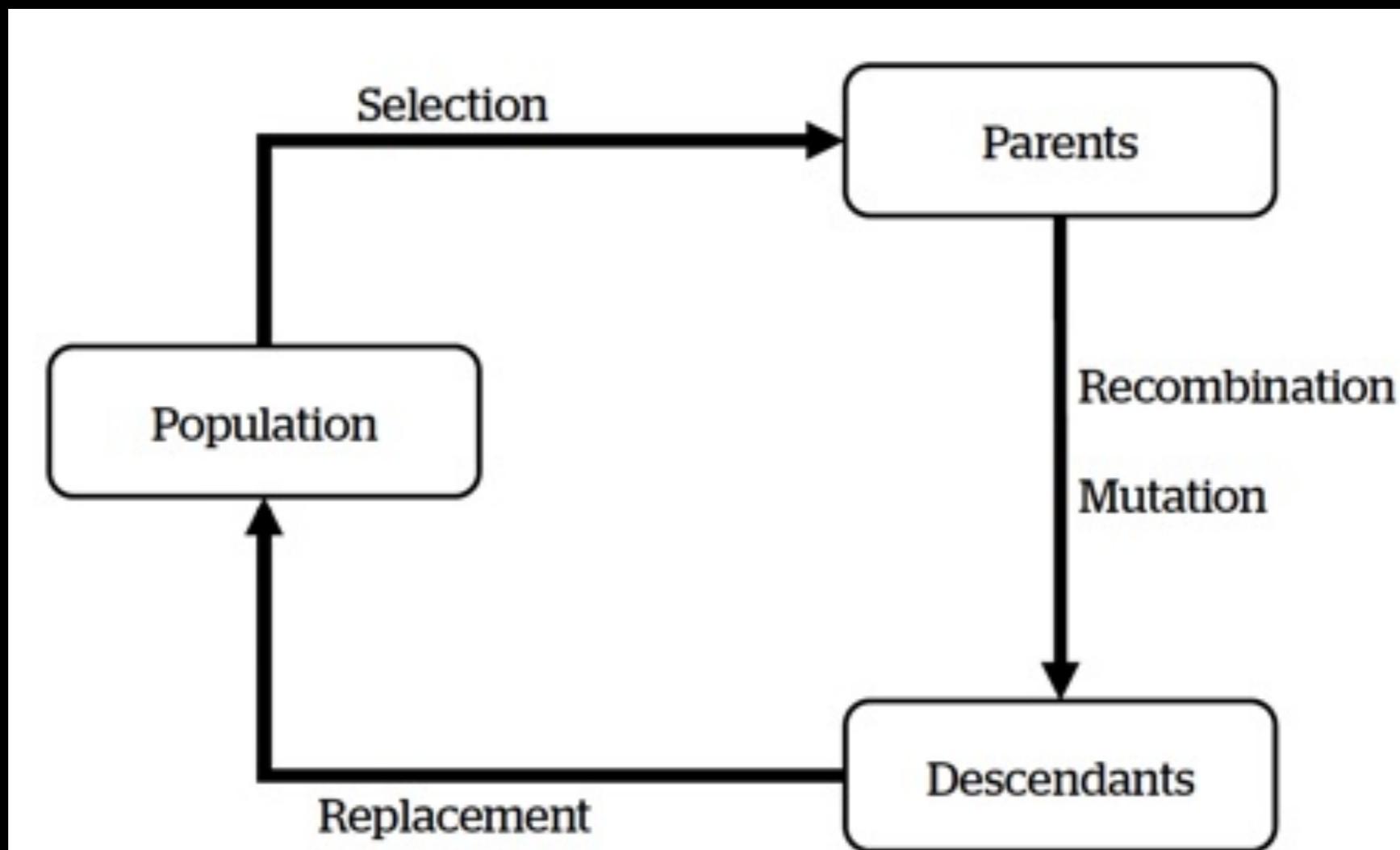
Machine learning

Given data instances X and label Y : Generative Model captures the joint probability $p(X, Y)$, or just $p(X)$ if there are no labels.



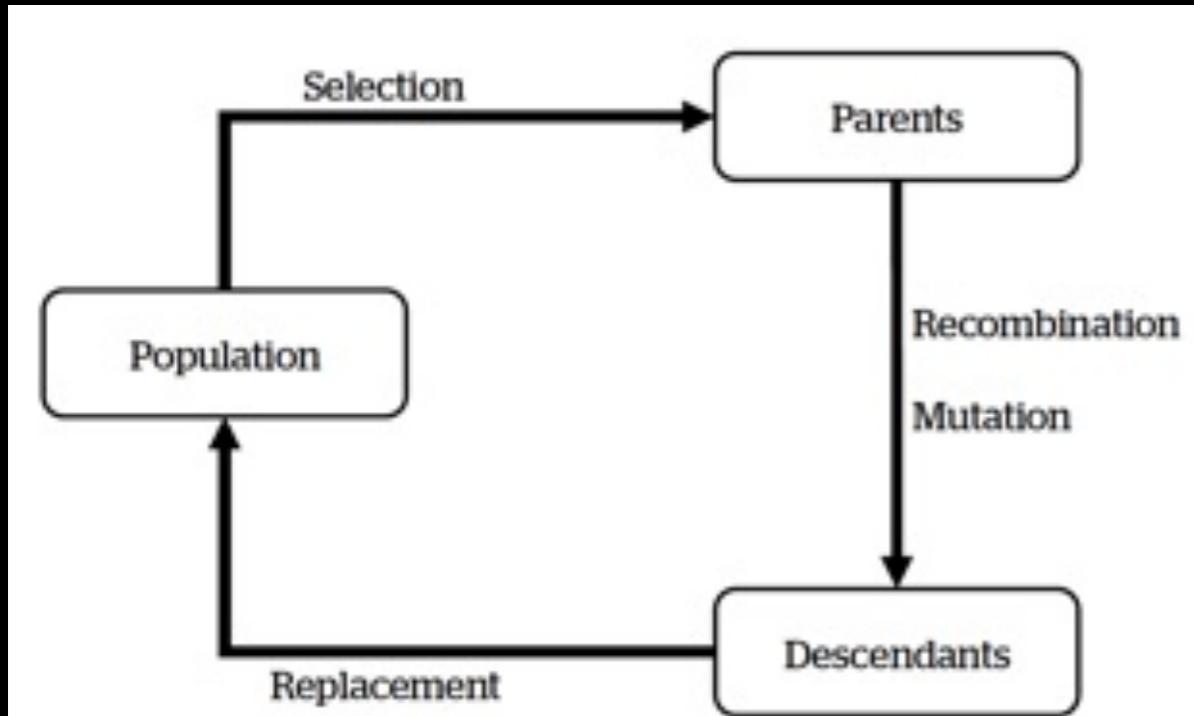
Generative Model

Evolutionary



Generative Model

Evolutionary + Machine Learning (EML)

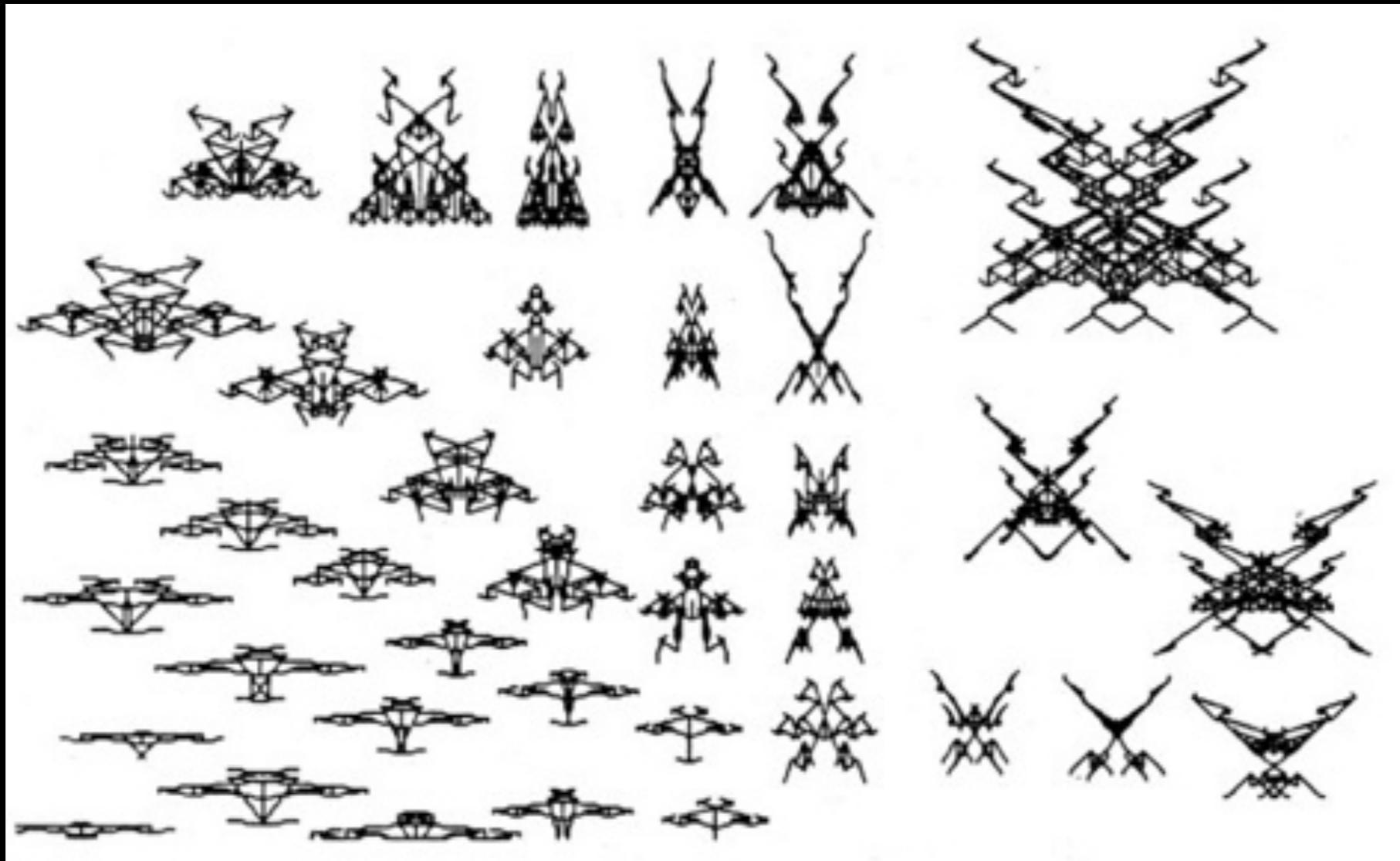


+



Generation of Computer Graphics

Richard Dawkins



William Latham



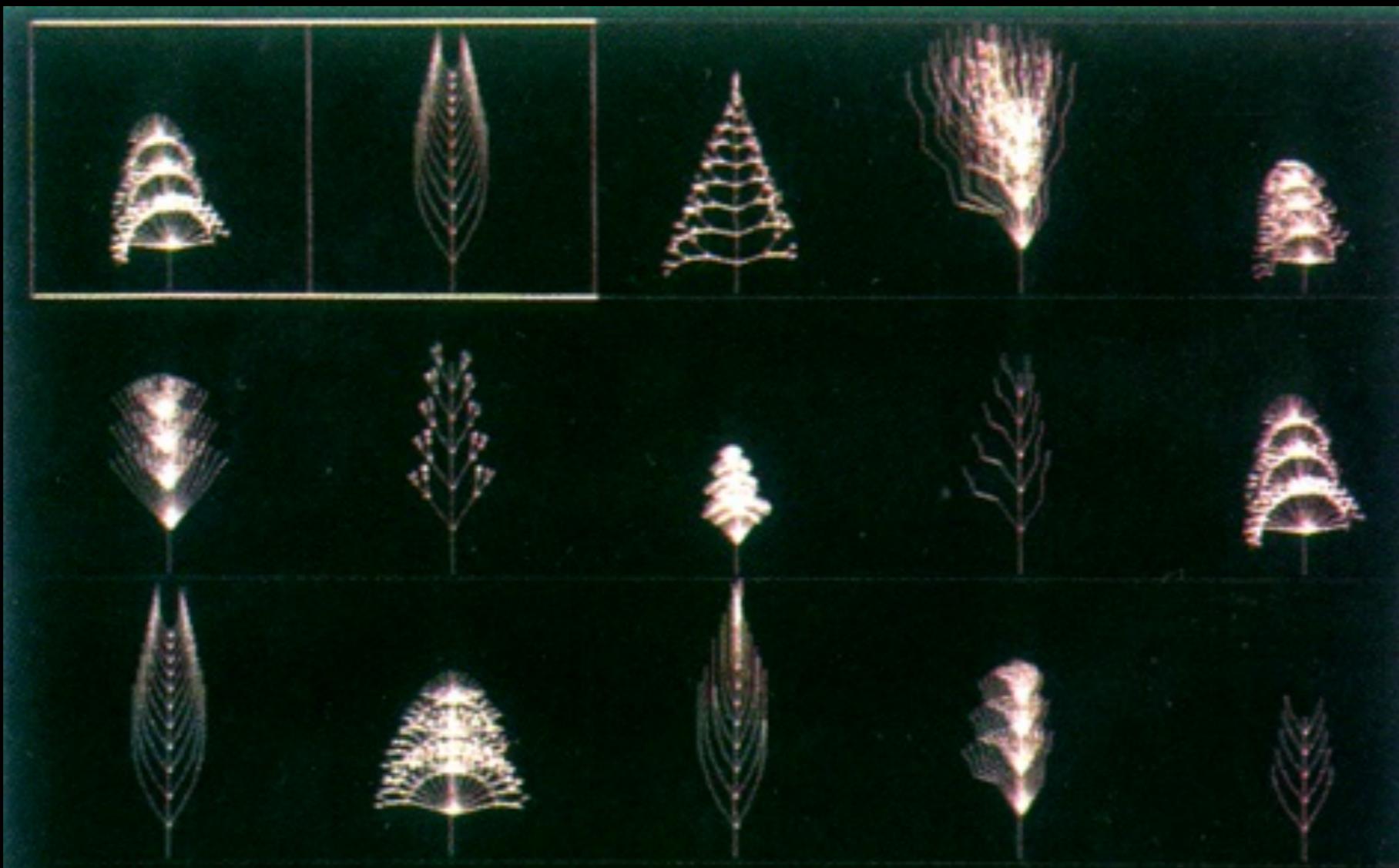
"BLACK FORM SYNTH"

WILLIAM LATHAM, 1985

V&A COLLECTION

[HTTPS://COLLECTIONS.VAM.AC.UK/ITEM/01276894/BLACK-FORM-SYNTH-OFFSET-LITHOGRAPH-WILLIAM-LATHAM/](https://collections.vam.ac.uk/item/01276894/black-form-synth-offset-lithograph-william-latham/)

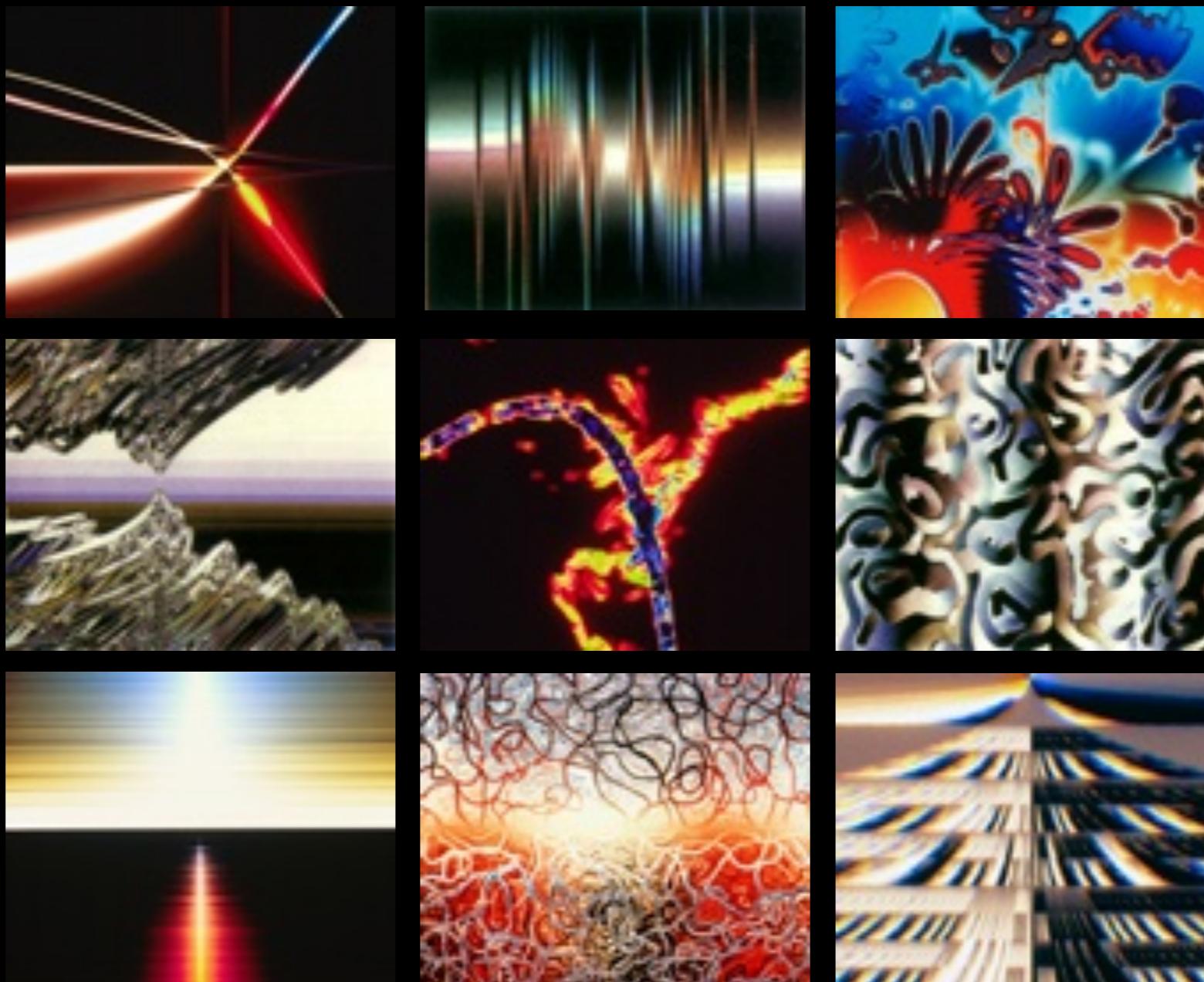
KARL SIMS



PLANT LIKE SHAPES

SIMS, K.: ARTIFICIAL EVOLUTION FOR COMPUTER GRAPHICS. SIGGRAPH '91 PROCEEDINGS: 319-328. 1991

KARL SIMS



EXPRESSION BASED IMAGES

SIMS, K.: ARTIFICIAL EVOLUTION FOR COMPUTER GRAPHICS. SIGGRAPH '91 PROCEEDINGS: 319-328. 1991

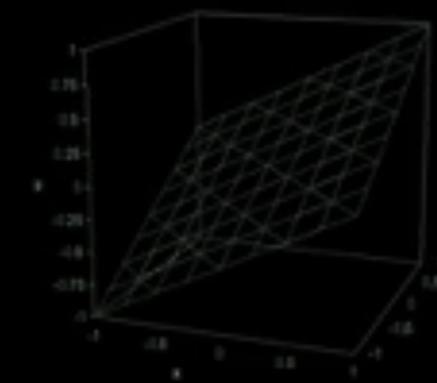
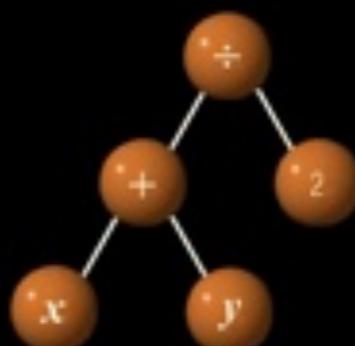
EXPRESSION BASED EVOLUTION

REPRESENTATION

THE INDIVIDUALS ARE TREES

FUNCTION SET

$+$, $-$, \times , $\%$, SIN, IF, XOR, ...



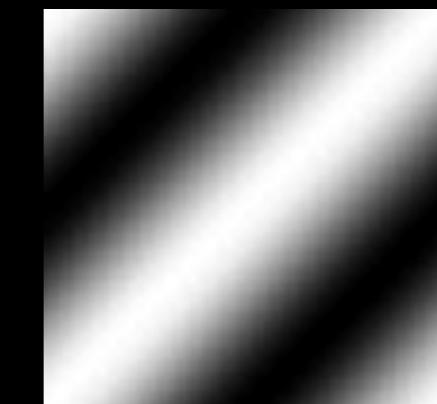
TERMINAL SET

X, Y, CONSTANTS

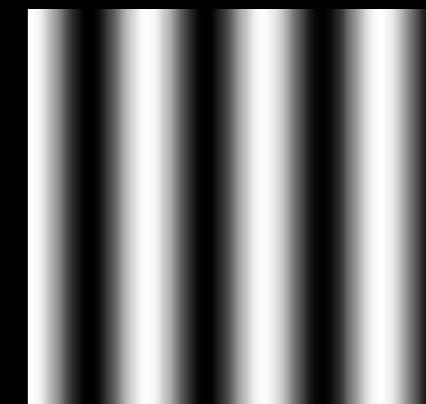
3D-VECTORS (FOR COLOR)



X



$\cos(x+y)$

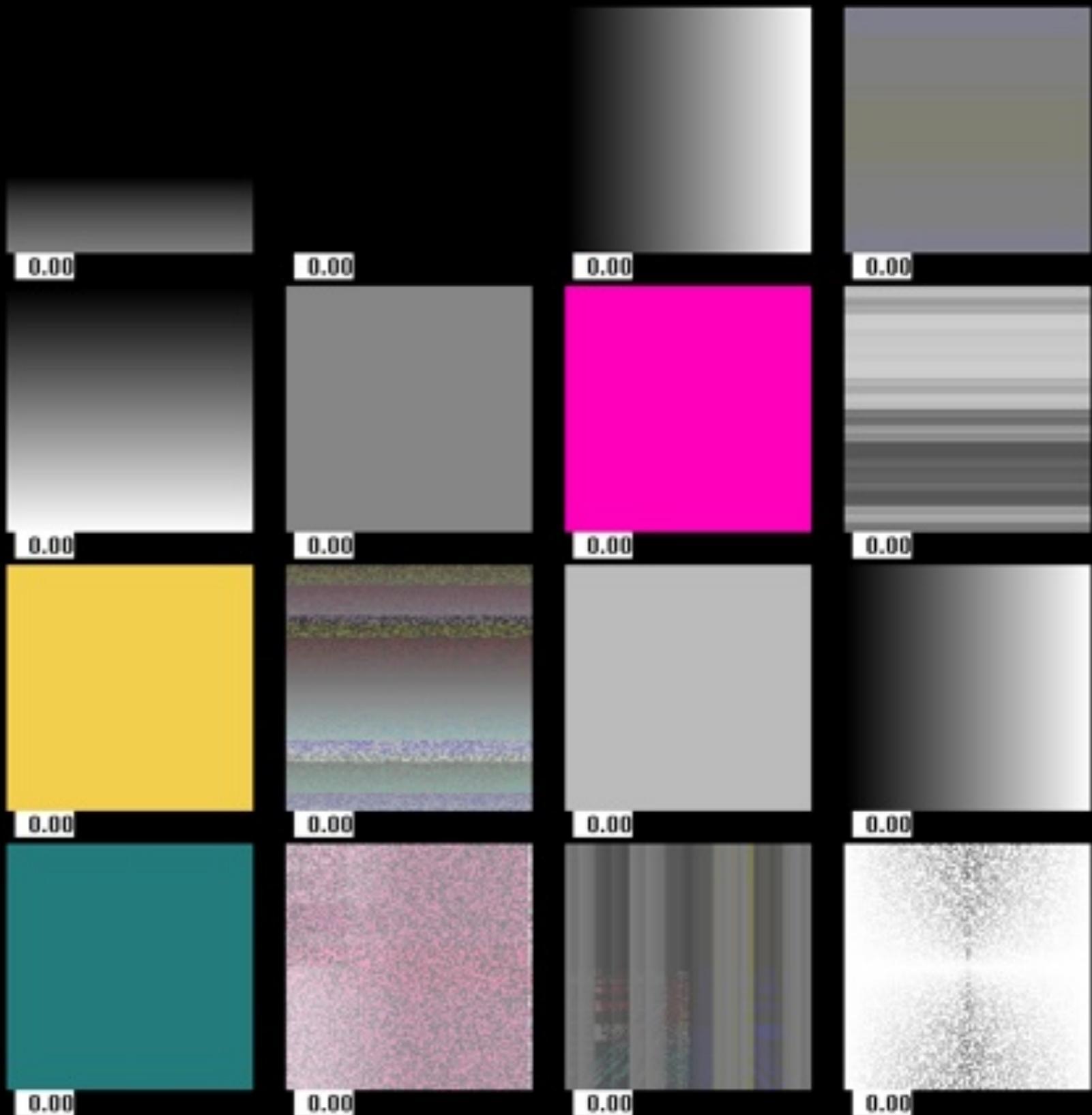


$\cos(4*x)$

P. MACHADO AND A. CARDOSO, "ALL THE TRUTH ABOUT NEVAR," APPLIED INTELLIGENCE, SPECIAL ISSUE ON CREATIVE SYSTEMS, VOL. 16, ISS. 2, PP. 101-119, 2002.

EXPRESSION BASED EVOLUTION

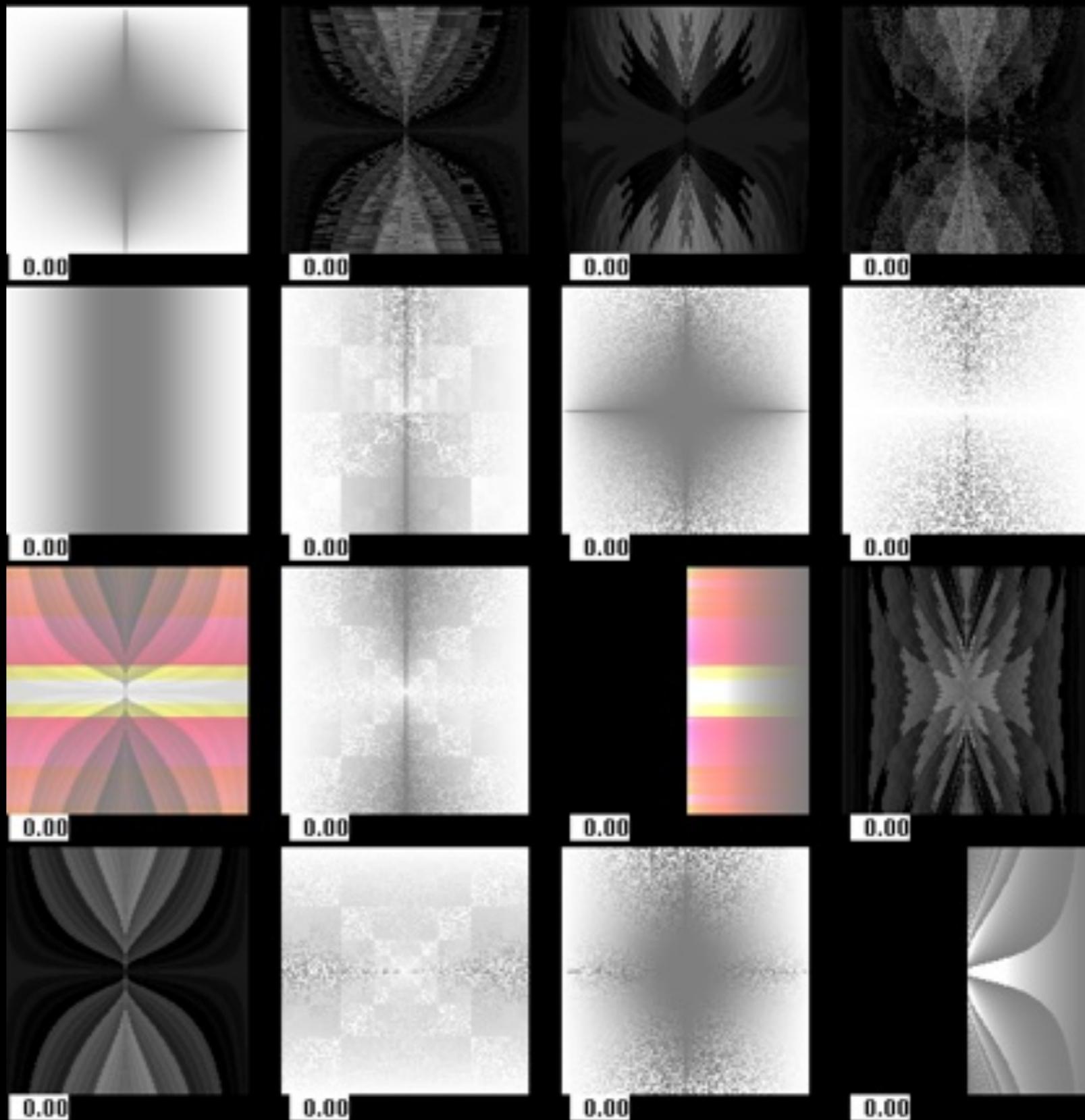
1ST GENERATION



P. MACHADO AND A. CARDOSO, "ALL THE TRUTH ABOUT NEVAR," APPLIED INTELLIGENCE, SPECIAL ISSUE ON CREATIVE SYSTEMS, VOL. 16, ISS. 2, PP. 101-119, 2002.

EXPRESSION BASED EVOLUTION

3RD GENERATION

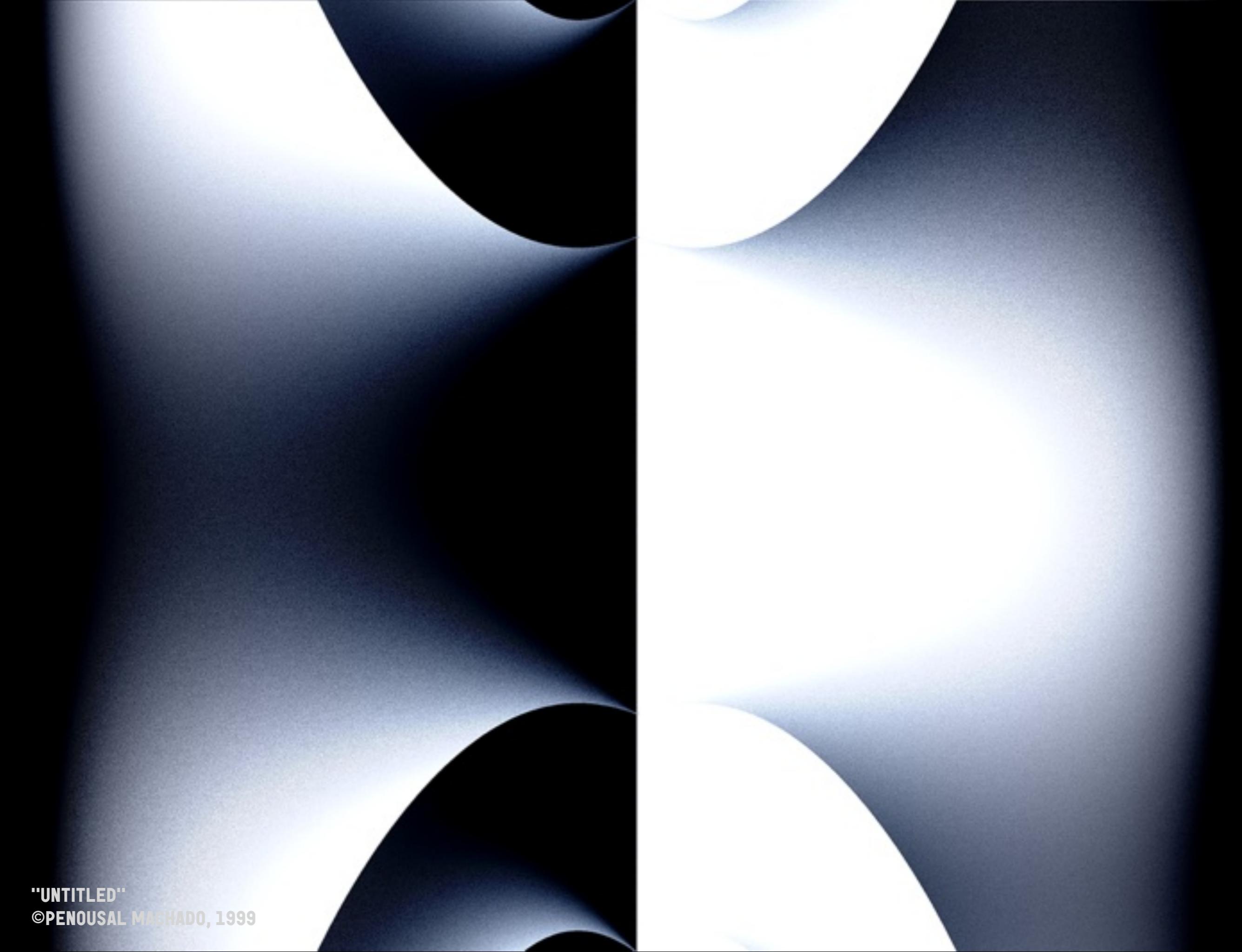


P. MACHADO AND A. CARDOSO, "ALL THE TRUTH ABOUT NEVAR," APPLIED INTELLIGENCE, SPECIAL ISSUE ON CREATIVE SYSTEMS, VOL. 16, ISS. 2, PP. 101-119, 2002.



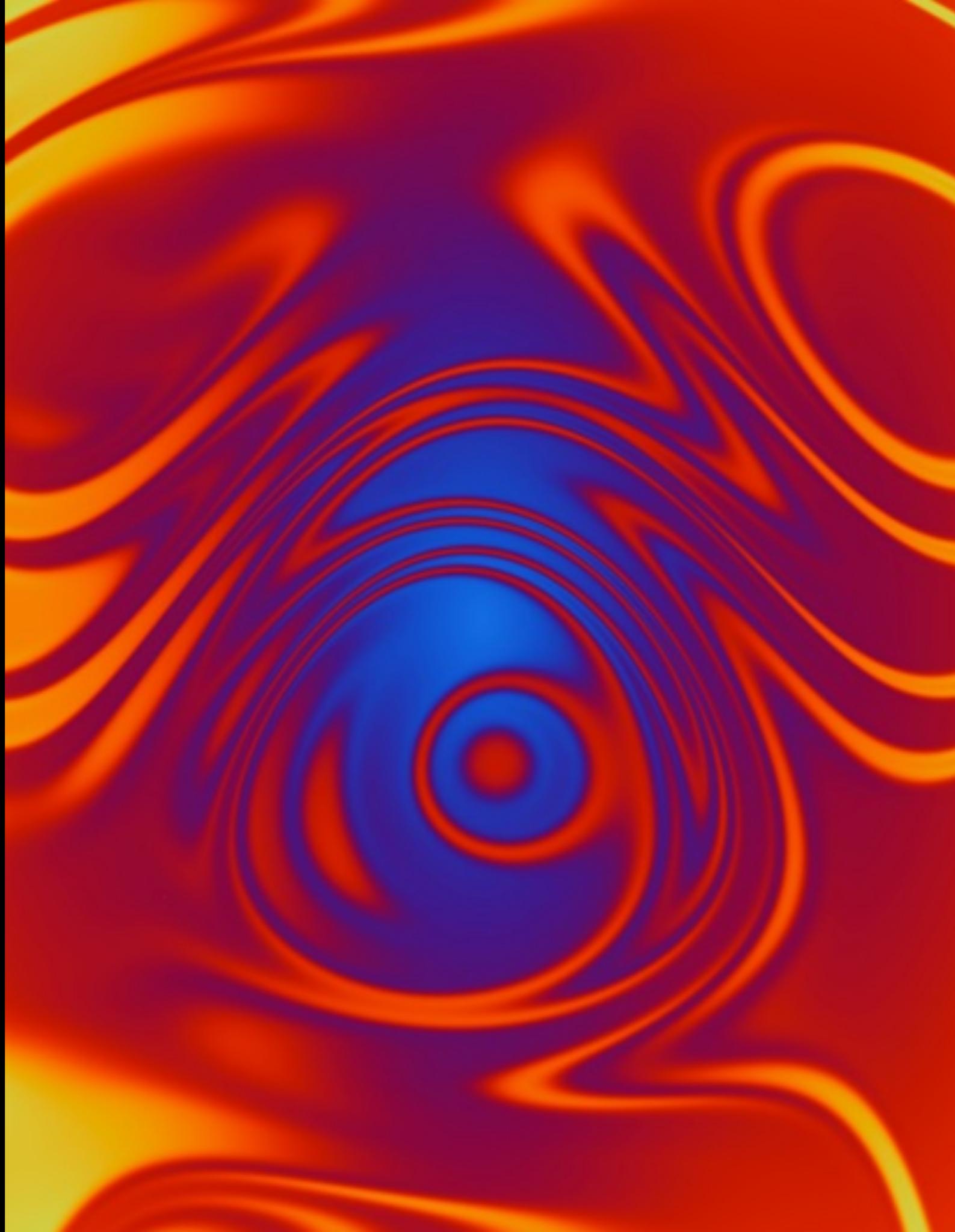
"UNTITLED"

©PENOUSAL MACHADO, 1999



"UNTITLED"

©PENOUSAL MACHADO, 1999



"UNTITLED"
©PENOUSAL MACHADO, 1999



"UNTITLED"

©PENOUSAL MACHADO, 1999

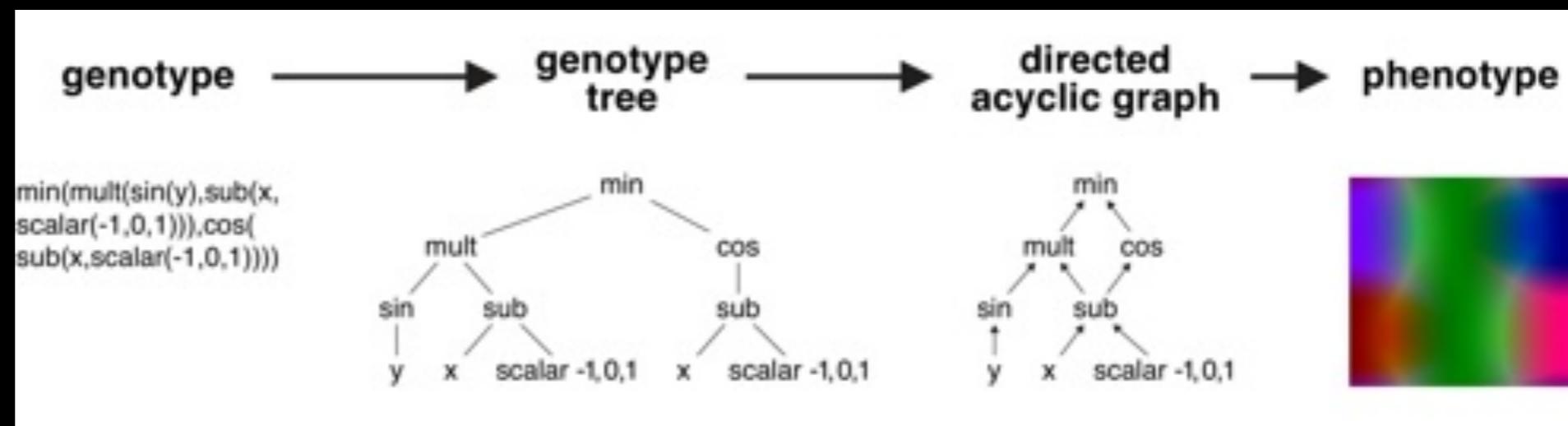
TENSORGP

REPRESENTATION

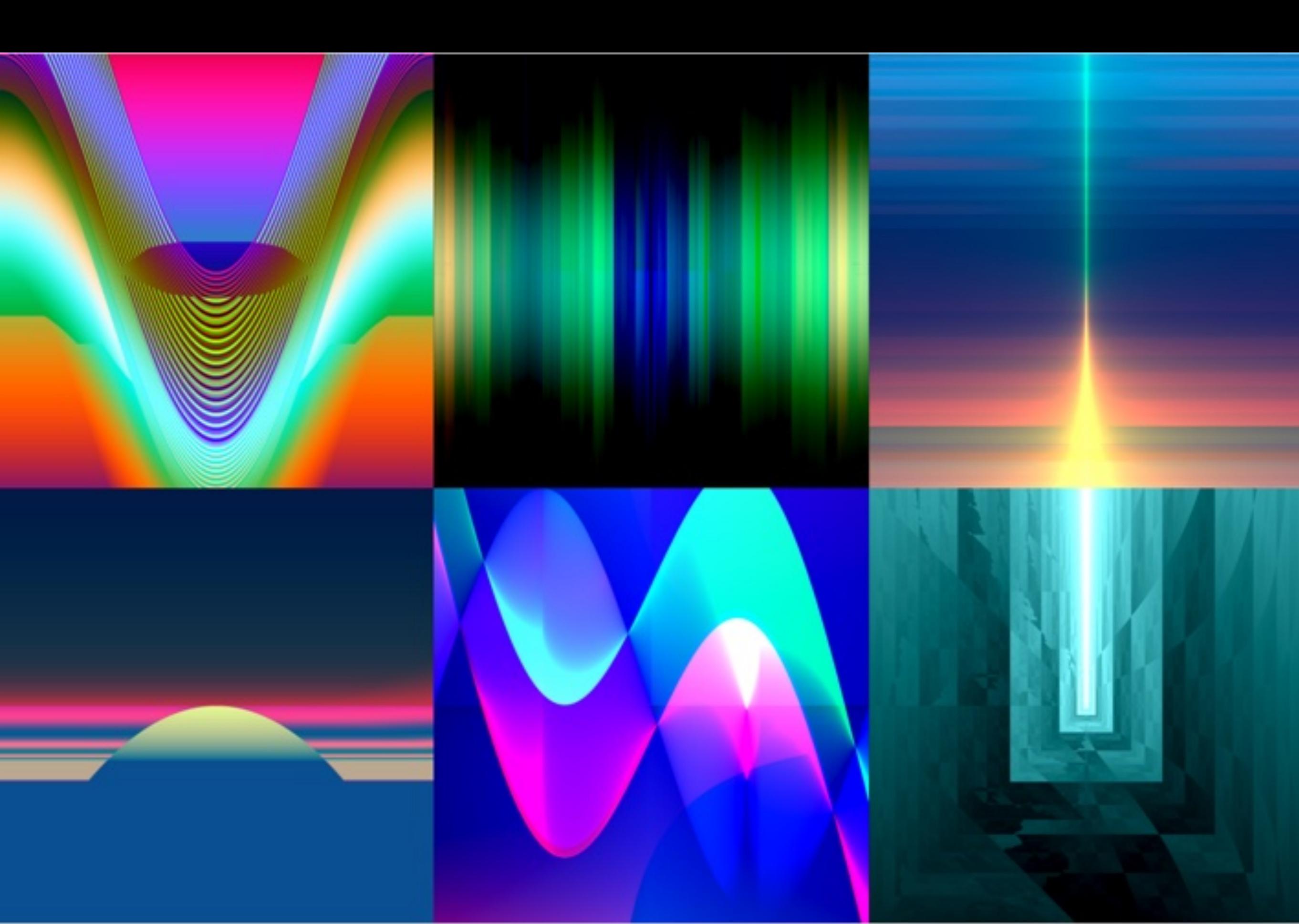
THE INDIVIDUALS ARE TREES

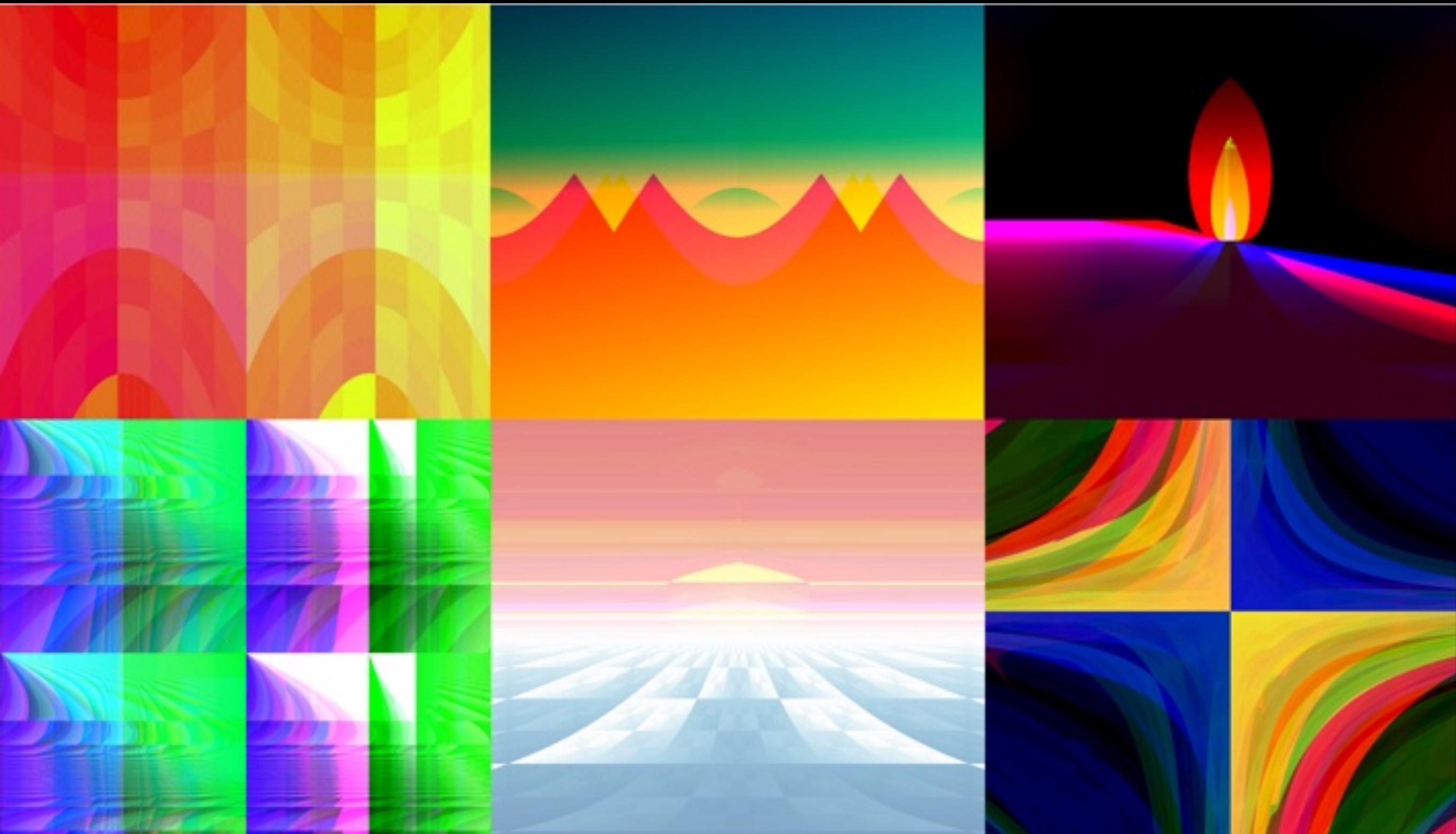
CONVERTED TO VECTOR REPRESENTATION

OPERATE ON THE GPU



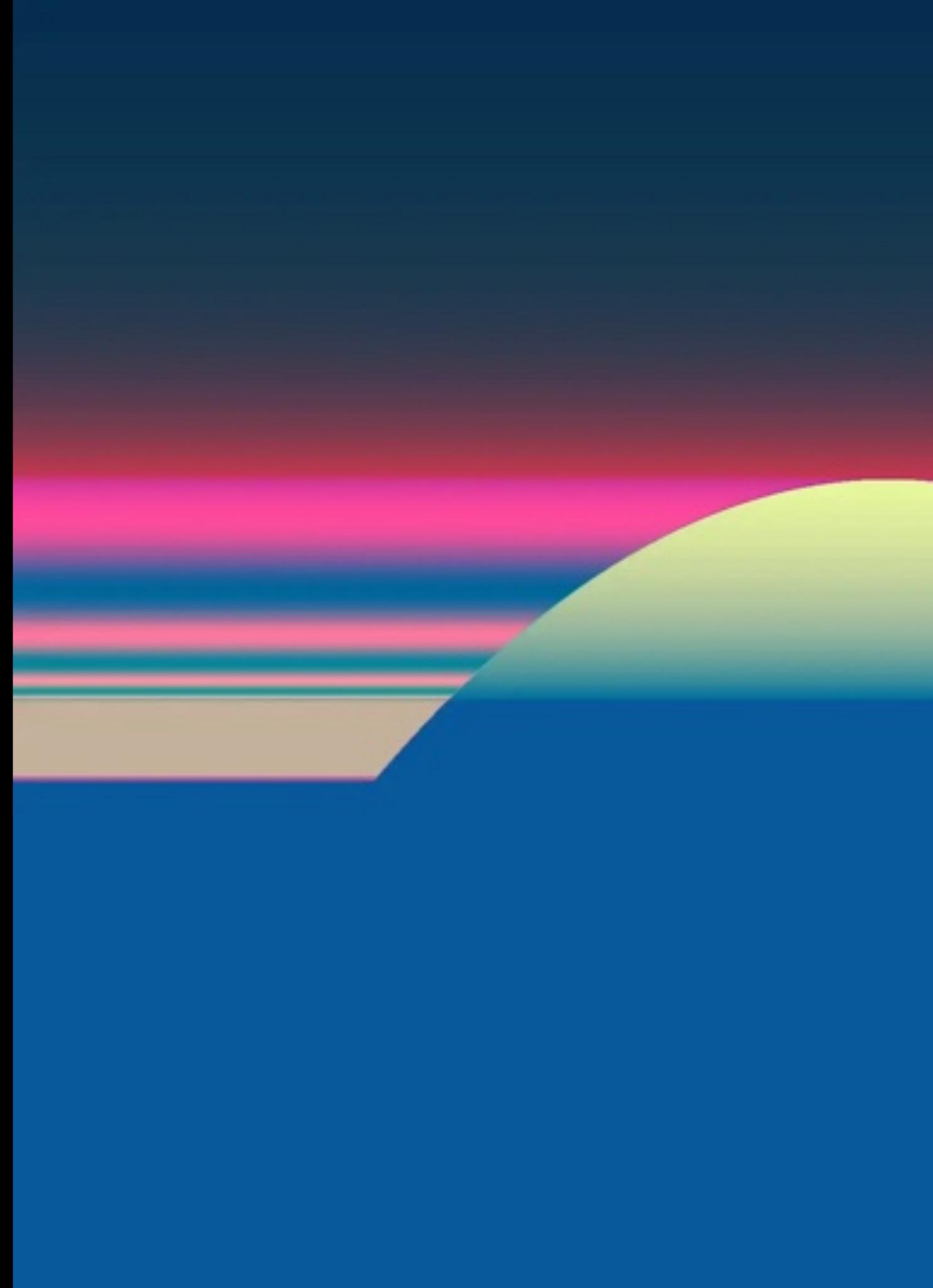
BAETA, F., CORREIA, J., MARTINS, T., MACHADO, P. (2021). TENSORGP – GENETIC PROGRAMMING ENGINE IN TENSORFLOW. IN: CASTILLO, P.A., JIMÉNEZ LAREDO, J.L. (EDS) APPLICATIONS OF EVOLUTIONARY COMPUTATION. EVOAPPLICATIONS 2021.





Key Aspects

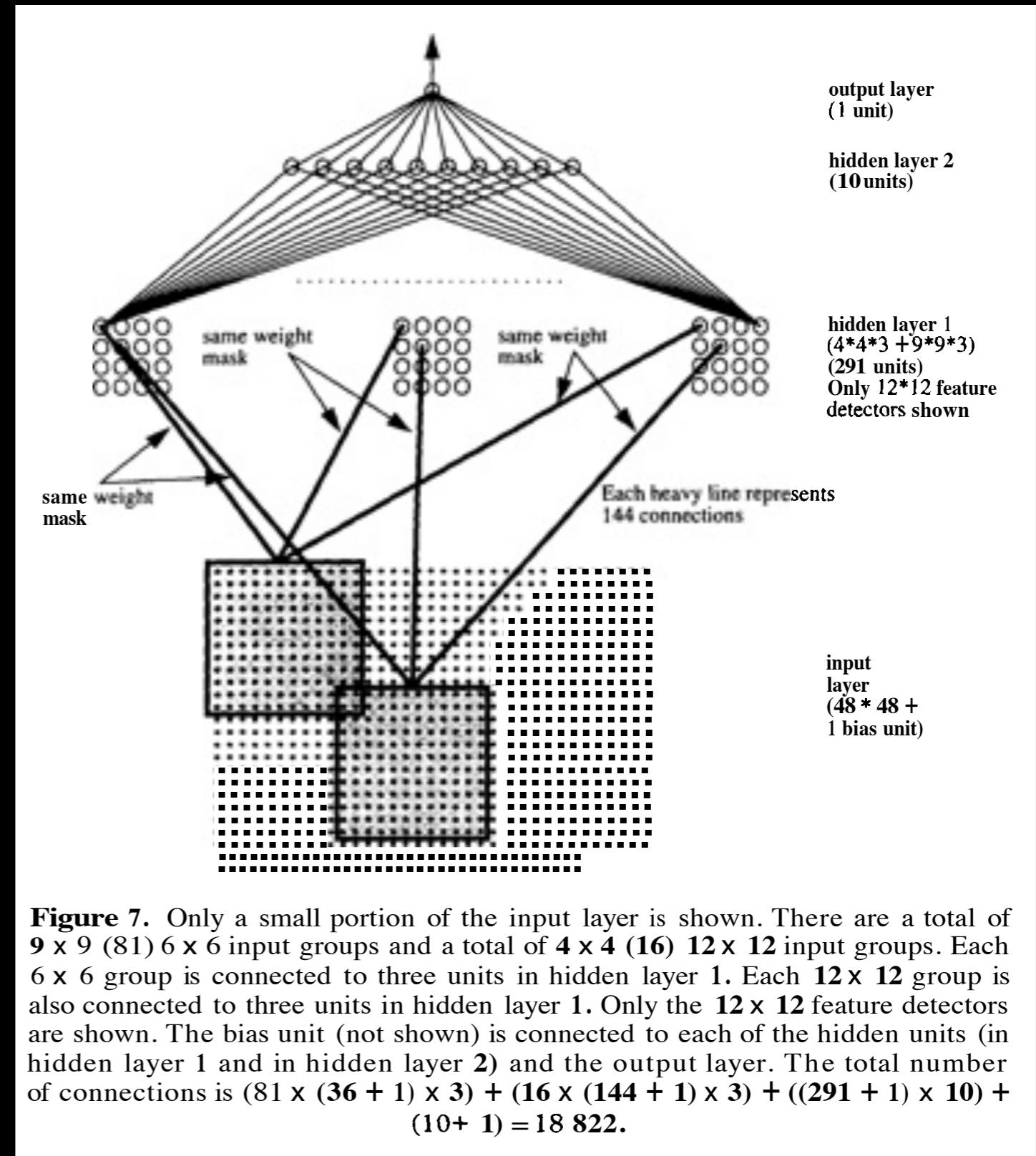
- Not Data Driven
- Taylor-made
- Interactive or Hardwired Functions



Machine Learning as Evaluators

MACHINE LEARNING

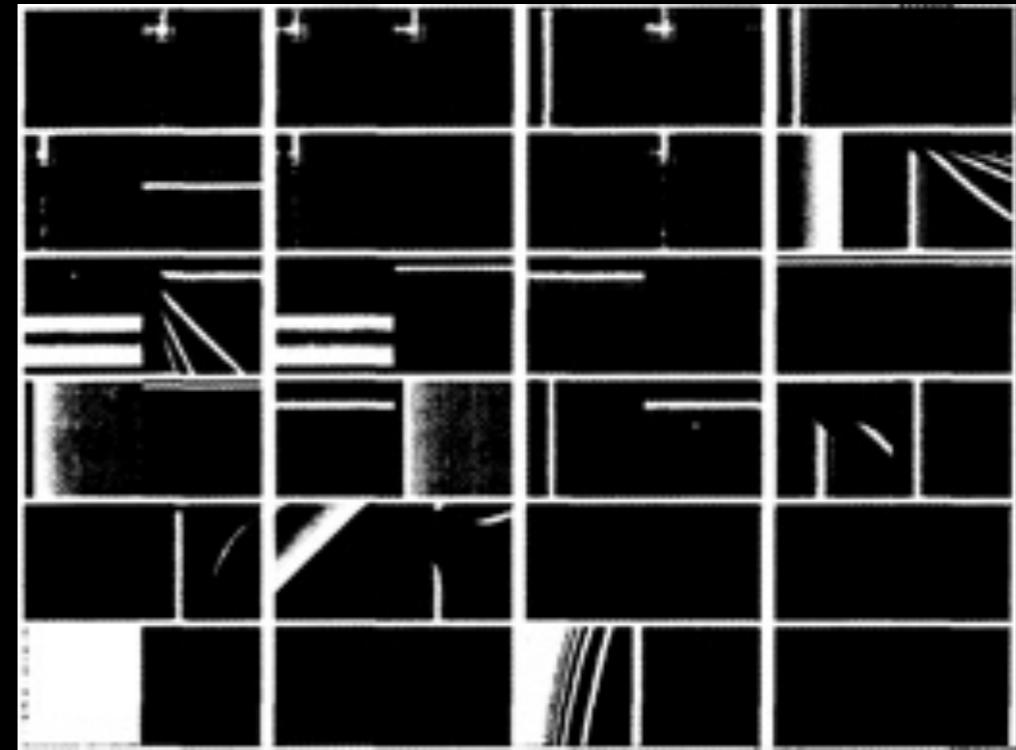
LEARNING USER PREFERENCES



MACHINE LEARNING

RESULTS

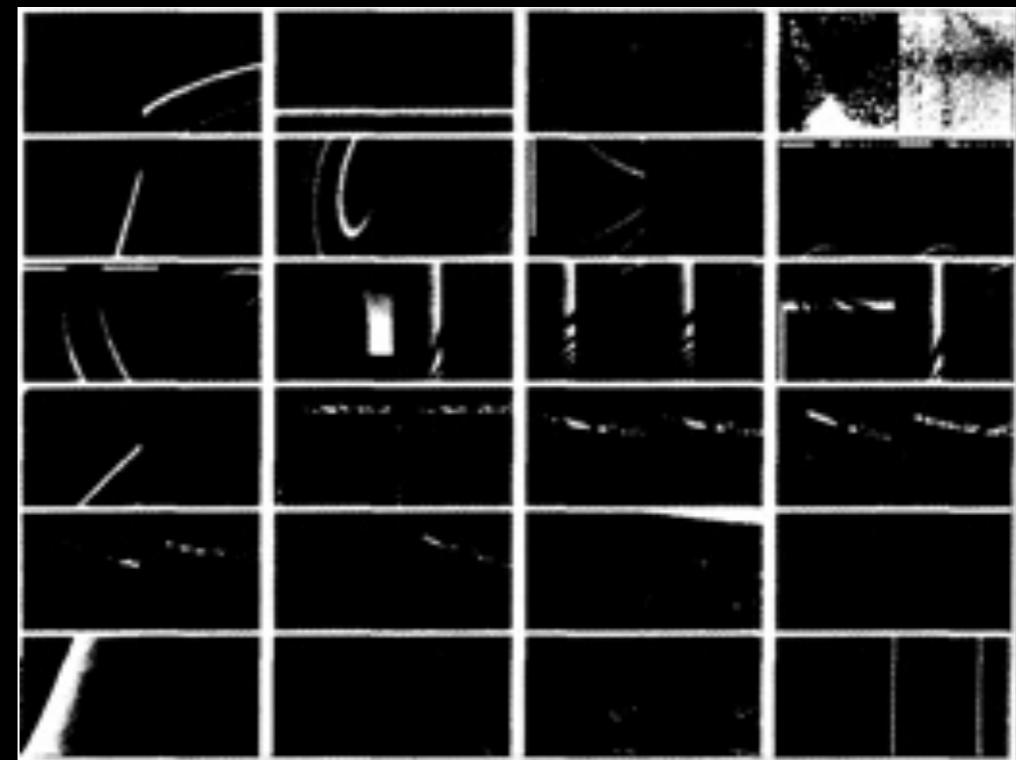
RANDOM VS. GUIDED BY THE ANN.



WHY?

GP IS FINDING SHORTCUTS.

SPECTOR, L., ALPERN, A.:
INDUCTION AND RECAPITULATION
OF DEEP MUSICAL STRUCTURE.
IJCAI-95 WORKSHOP ON
ARTIFICIAL INTELLIGENCE AND
MUSIC (1995) 41-48



BALUJA S, POMERLAU D, TODD J. TOWARDS AUTOMATED ARTIFICIAL EVOLUTION
FOR COMPUTER-GENERATED IMAGES. CONNECTION SCIENCE 1994; 6(2):325-54

MACHINE LEARNING

THE IDEA

**COMBINE A GENERAL PURPOSE
EVOLUTIONARY ART SYSTEM WITH AN
IMAGE CLASSIFIER TRAINED TO
RECOGNIZE FACES, OR OTHER TYPES
OF OBJECTS, TO EVOLVE IMAGES OF
HUMAN FACES.**

J. ROMERO, P. MACHADO, A. SANTOS, AND A.
CARDOSO, "ON THE DEVELOPMENT OF CRITICS
IN EVOLUTIONARY COMPUTATION ARTISTS,"
EVOWORKSHOP 2003, ESSEX, UK, APRIL
14-16, 2003, PROCEEDINGS, 2003, PP.
559-569.

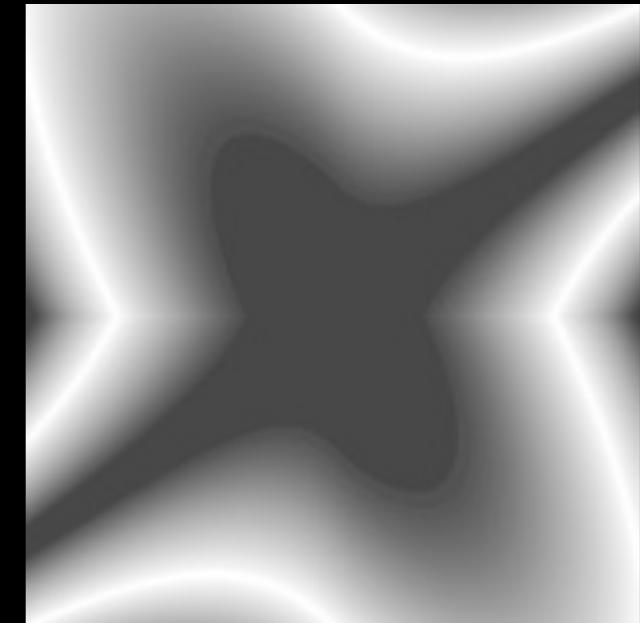
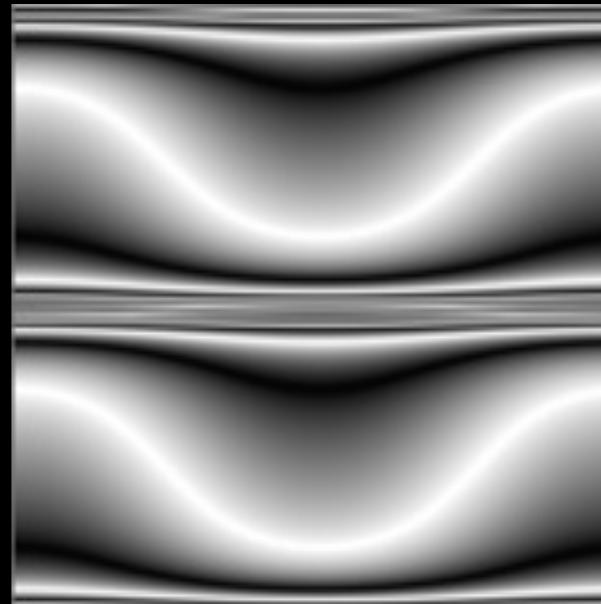
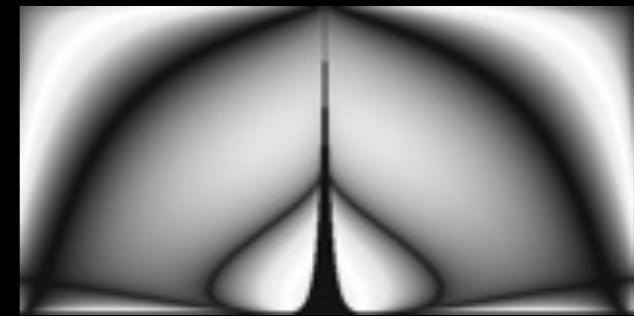
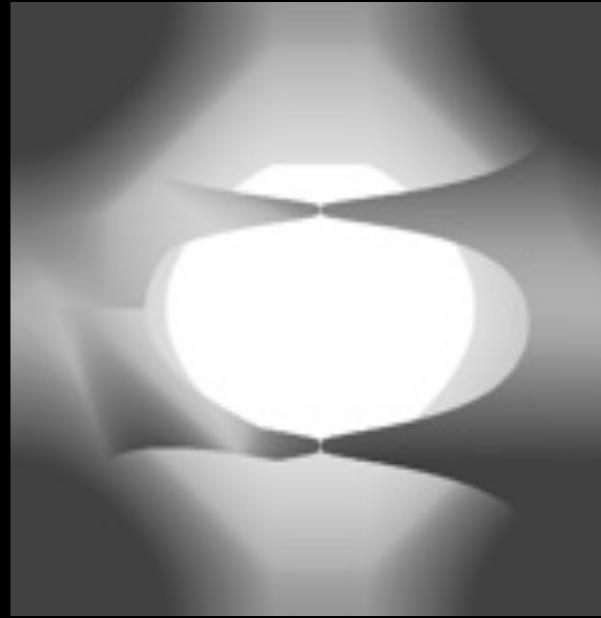
MACHINE LEARNING

EVOLVING FACES

THE EC SYSTEM ALWAYS FINDS
IMAGES THAT ARE RECOGNIZED AS
FACES.

OFTEN THESE IMAGES HAVE NO
RESEMBLANCE WITH A FACE.

P. MACHADO, J. CORREIA, AND J. ROMERO,
"EXPRESSION-BASED EVOLUTION OF FACES,"
EVOMUSART 2012, MÁLAGA, SPAIN, APRIL
11-13, 2012. PROCEEDINGS, 2012, PP.
187-198.



MACHINE LEARNING

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EVOMUSART 2012, MÁLAGA, SPAIN, APRIL
11-13, 2012. PROCEEDINGS, 2012, PP.
187-198.

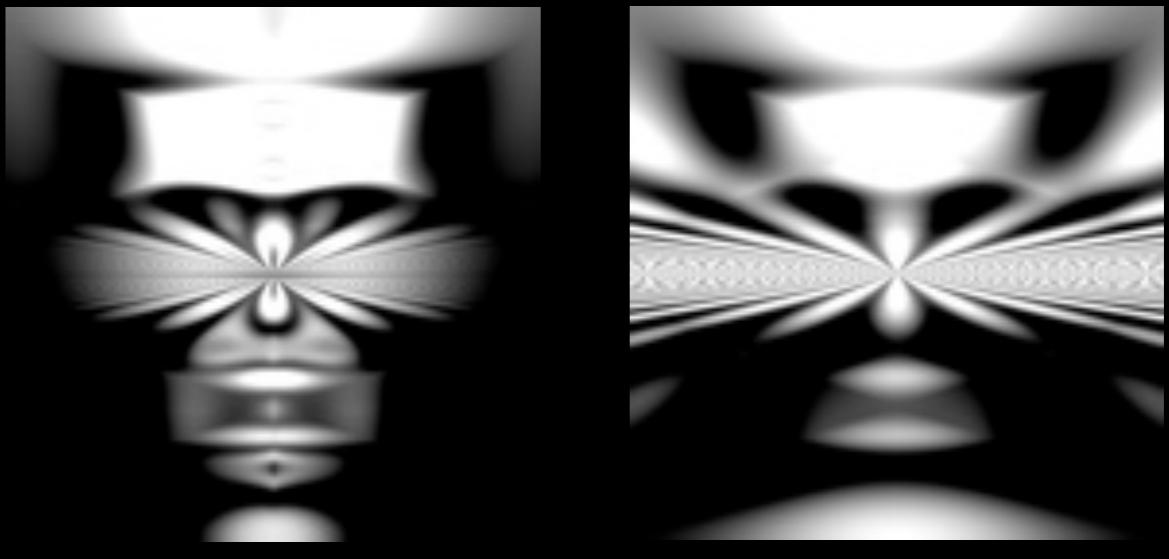
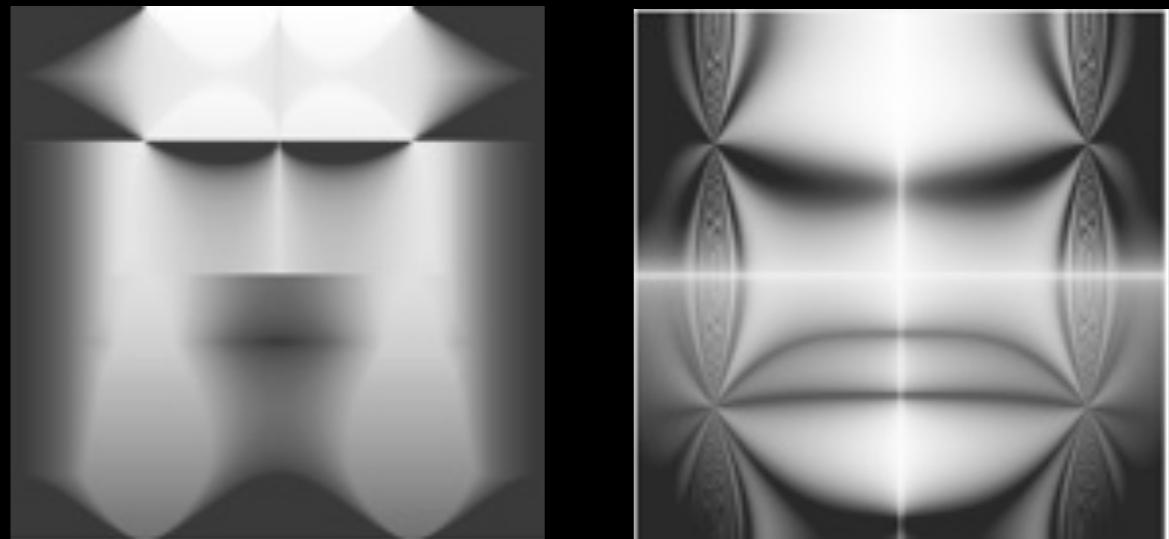


MACHINE LEARNING

EVOLVING FACES

SOME SUCCESS STORIES.

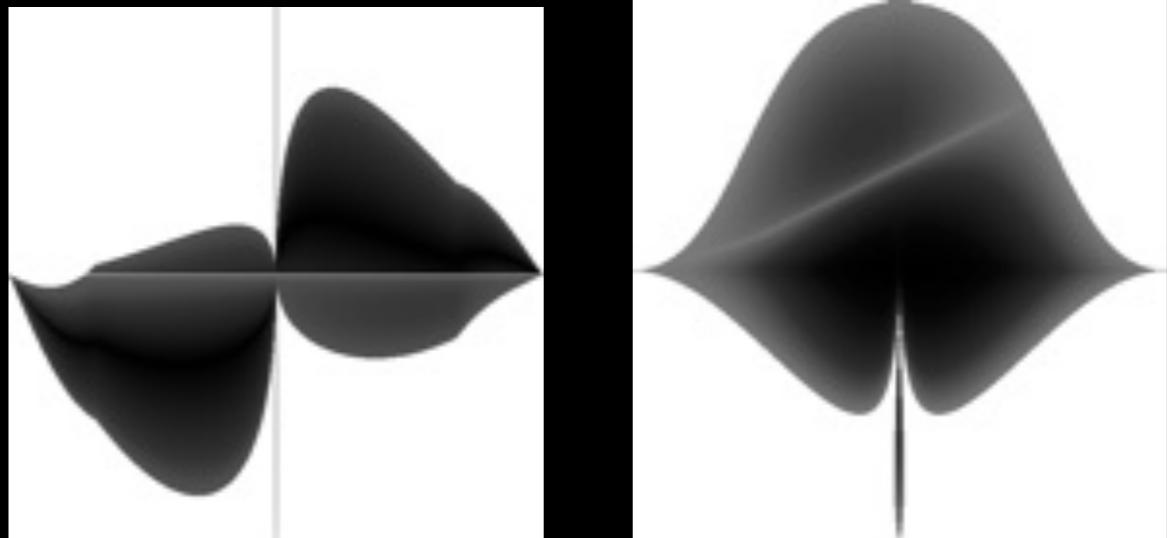
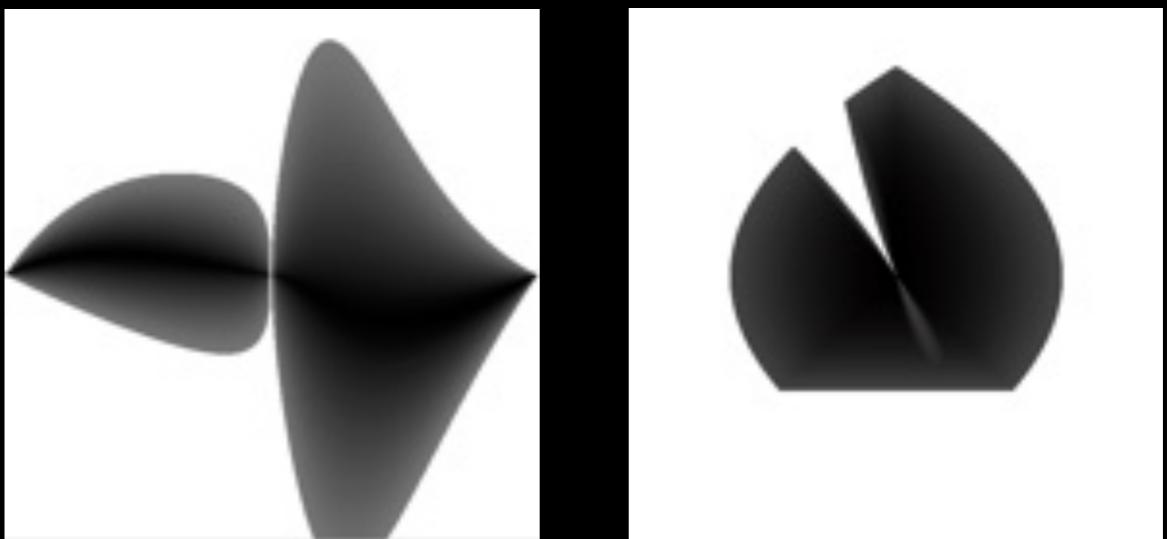
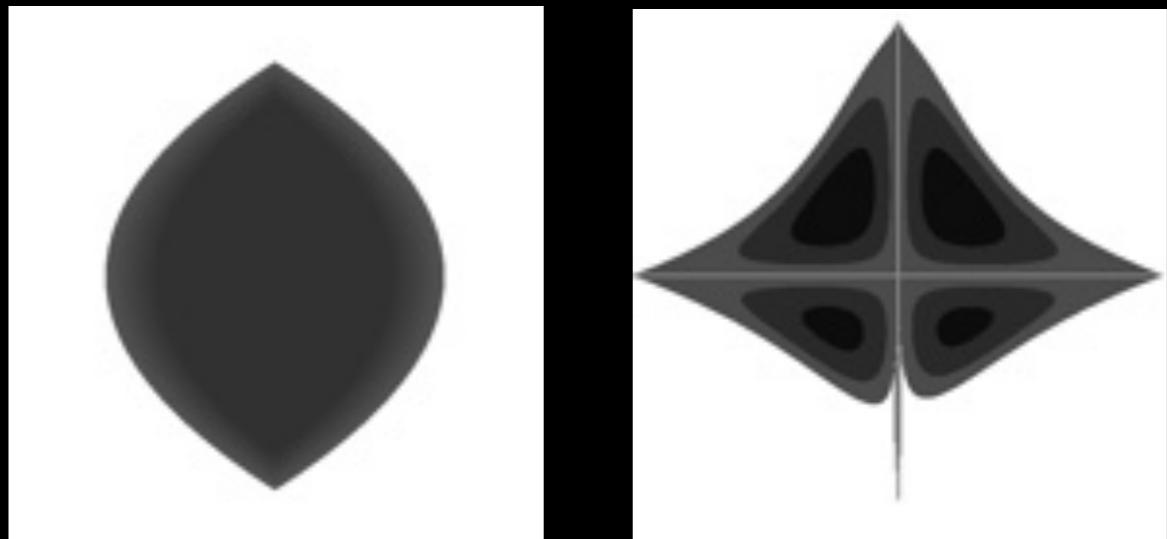
P. MACHADO, J. CORREIA, AND J. ROMERO,
"EXPRESSION-BASED EVOLUTION OF FACES,"
EVOMUSART 2012, MÁLAGA, SPAIN, APRIL
11-13, 2012. PROCEEDINGS, 2012, PP.
187-198.



MACHINE LEARNING

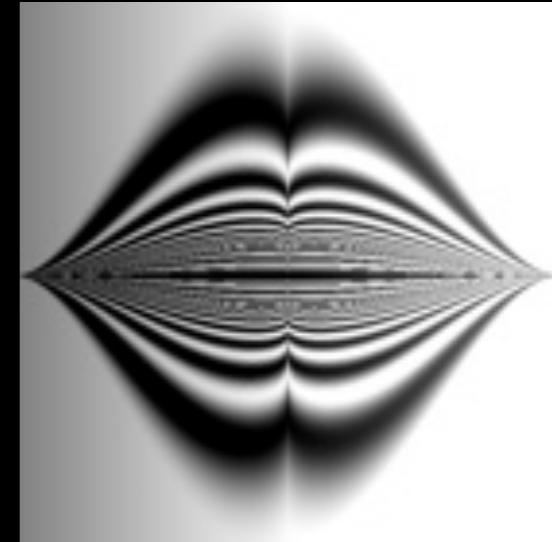
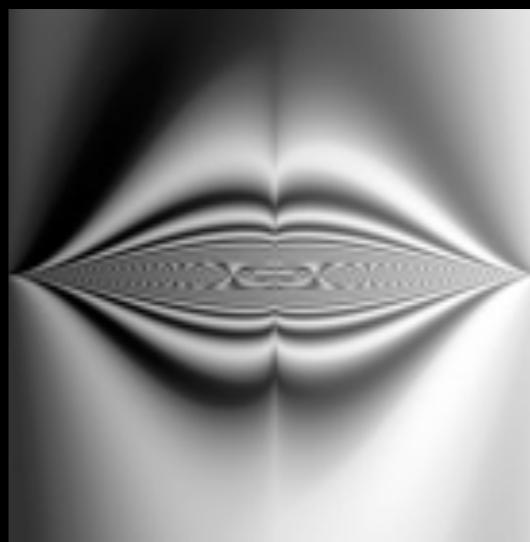
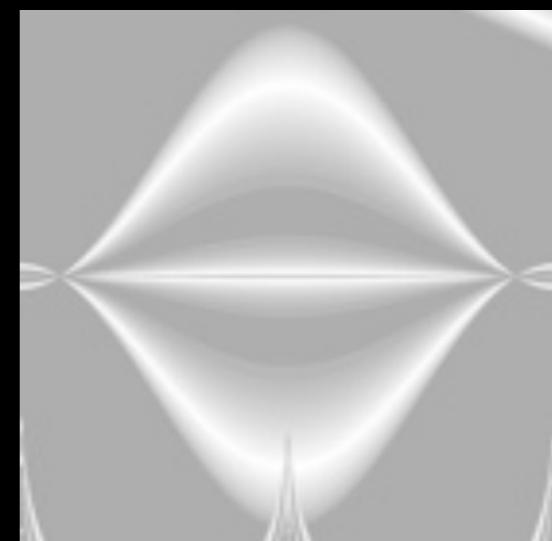
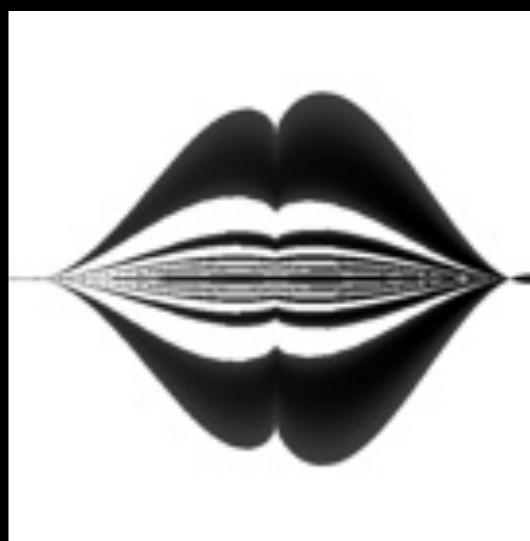
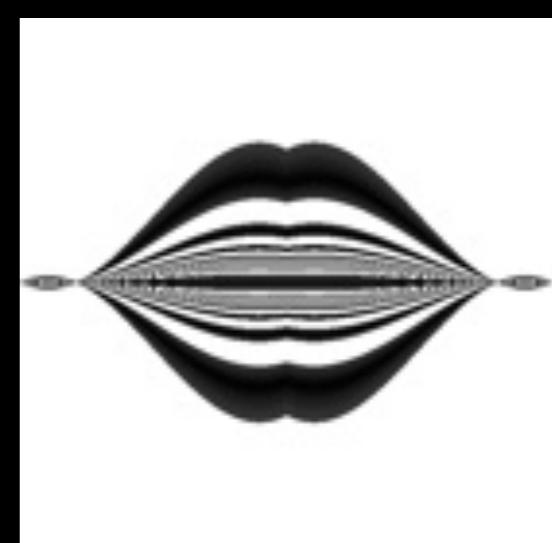
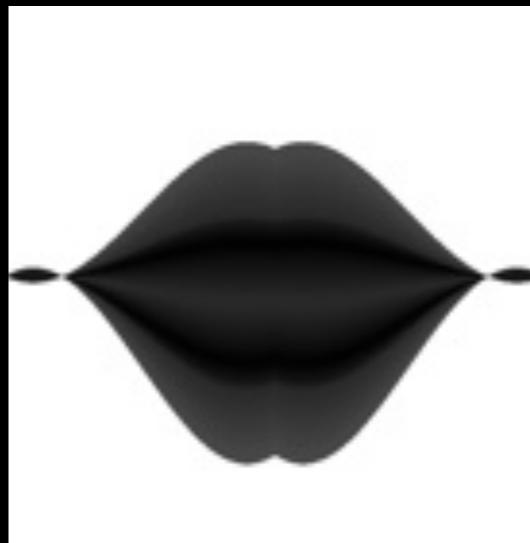
EVOLVING LEAFS

J. CORREIA, P. MACHADO, J. ROMERO, AND A.
CARBALLAL, "EVOLVING FIGURATIVE IMAGES
USING EXPRESSION-BASED EVOLUTIONARY
ART," ICCC 2013, PP. 24-31.



MACHINE LEARNING

EVOLVING LIPS



J. CORREIA, P. MACHADO, J. ROMERO, AND A.
CARBALLAL, "EVOLVING FIGURATIVE IMAGES
USING EXPRESSION-BASED EVOLUTIONARY
ART," ICCC 2013, PP. 24-31.

EFFECTIVE

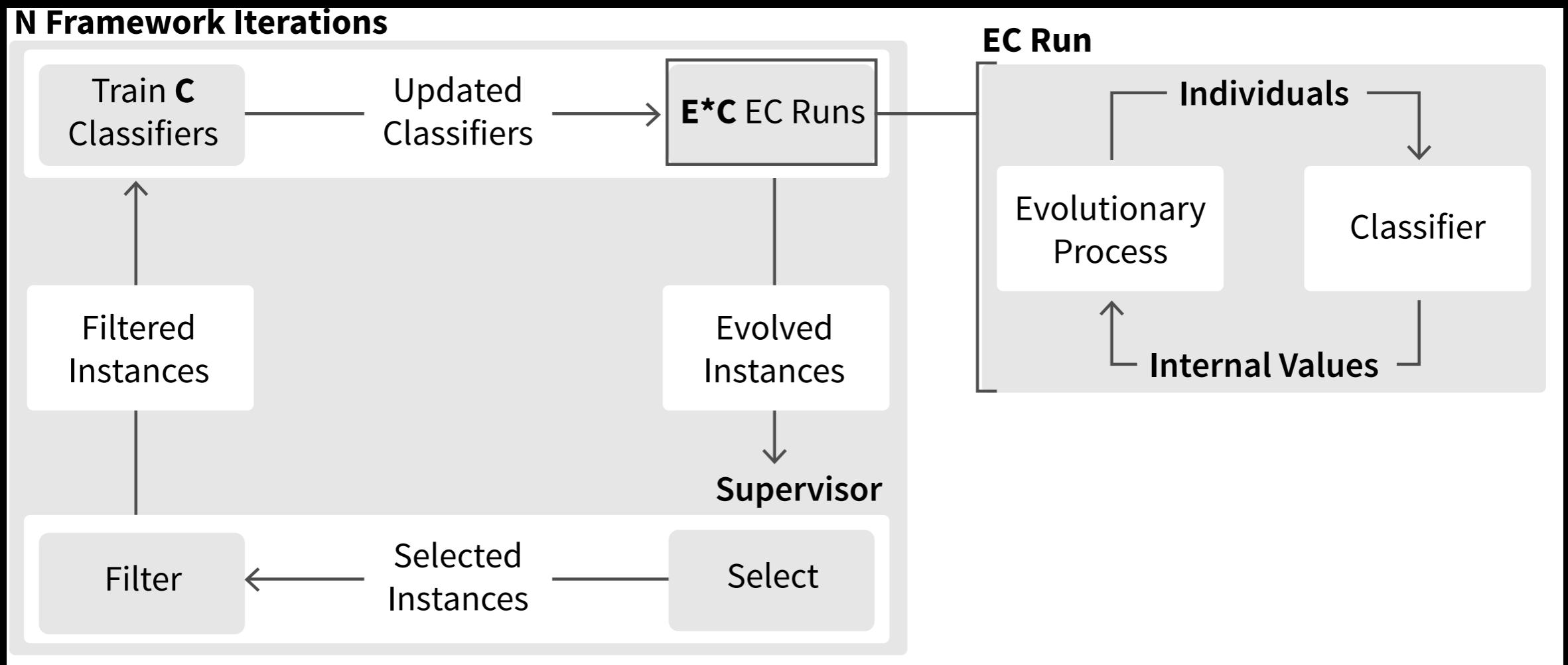
**EVOLUTIONARY FRAMEWORK FOR
CLASSIFIER ASSESSMENT AND
IMPROVEMENT (EFFECTIVE)**

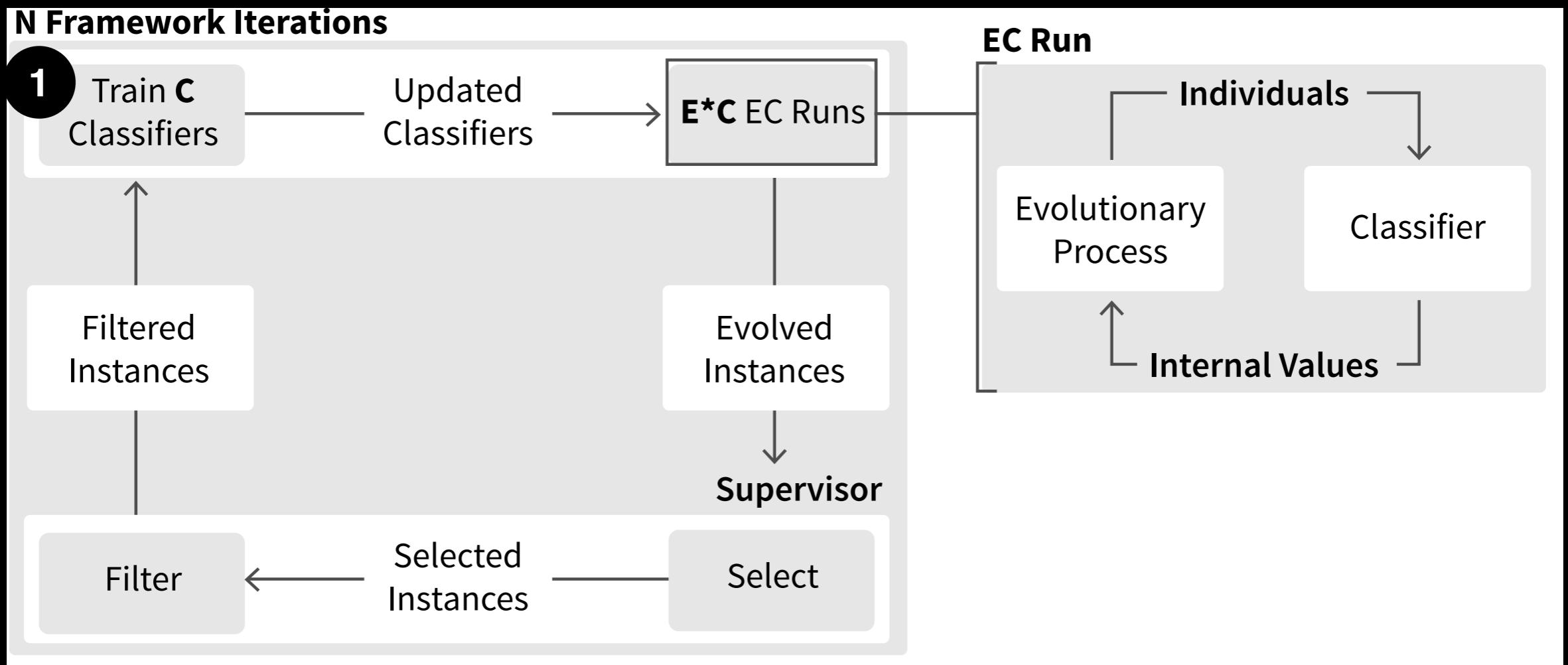
ADVERSARIAL FRAMEWORK

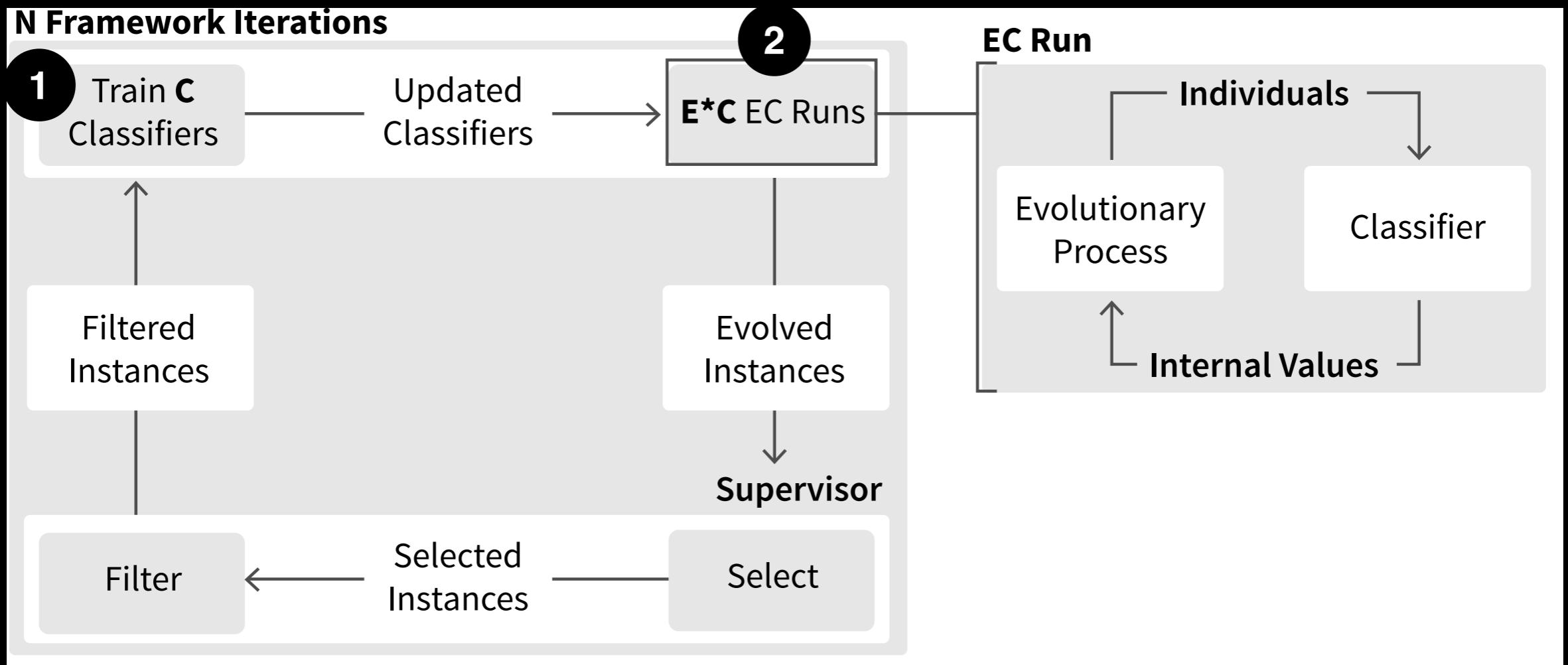
EC ENGINE

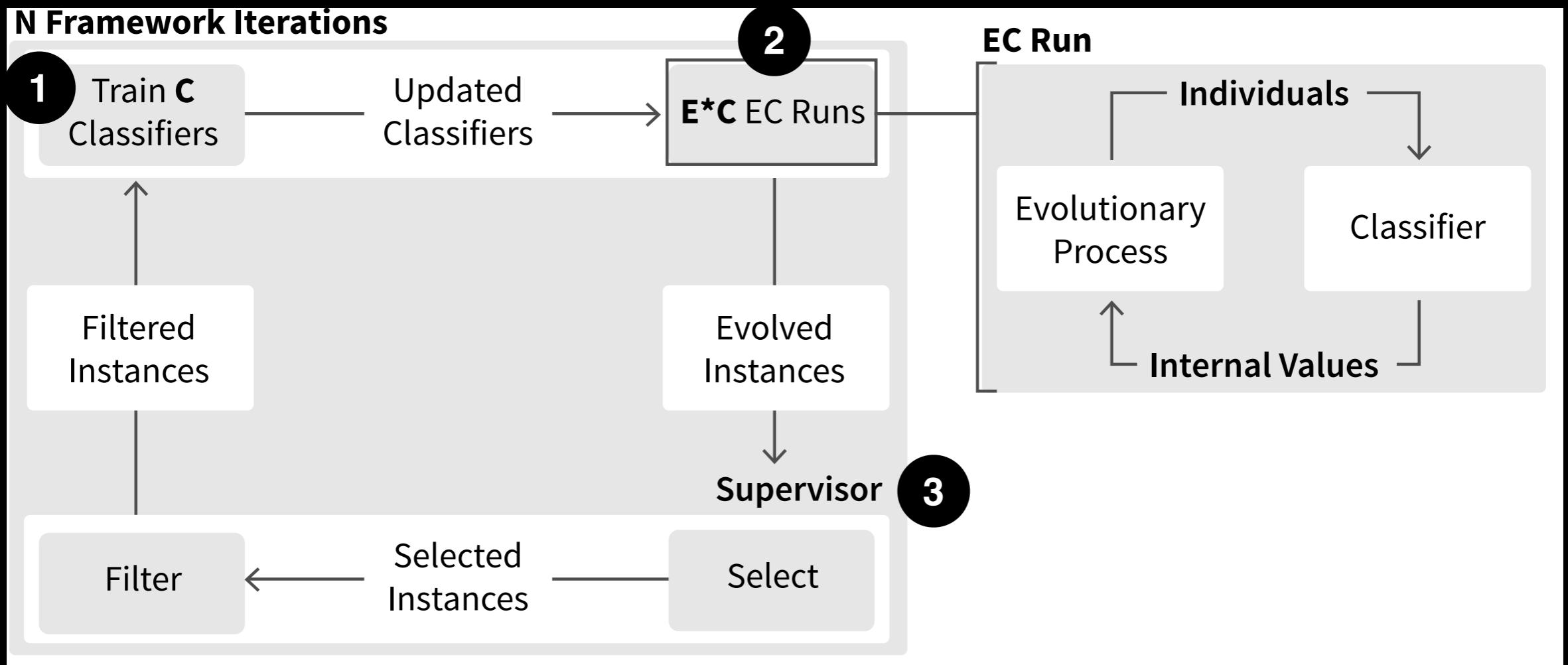
CLASSIFIER SYSTEM

SUPERVISOR











Test datasets: Flickr (top); FERET (middle); CMU-MIT (bottom)

EFFECTIVE

EXPERIMENTAL RESULTS

**IN THE LAST ITERATION, IN TERMS OF
AVG(%C):**

BASELINE: 60.5

EXPANDING NEGATIVE: 77.5

EXPANDING POSITIVE: 64.2

EXPANDING POSITIVE AND NEGATIVE: 79.3

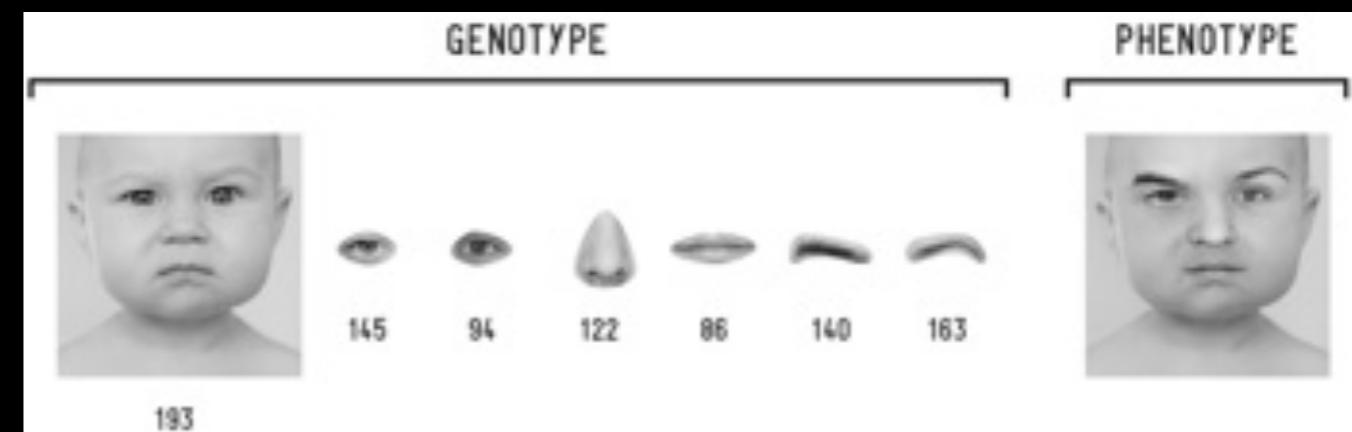
**HOW DID WE
EXPAND THE
POSITIVE SET?**

X-FACES

EVOLVING FACES



J. CORREIA, T. MARTINS, P. MARTINS, AND P.
MACHADO, "X-FACES: THE EXPLOIT IS OUT
THERE," ICCC 2016, PP. 164–182.





Facial parts automatically extracted from existing face images

X-FACES

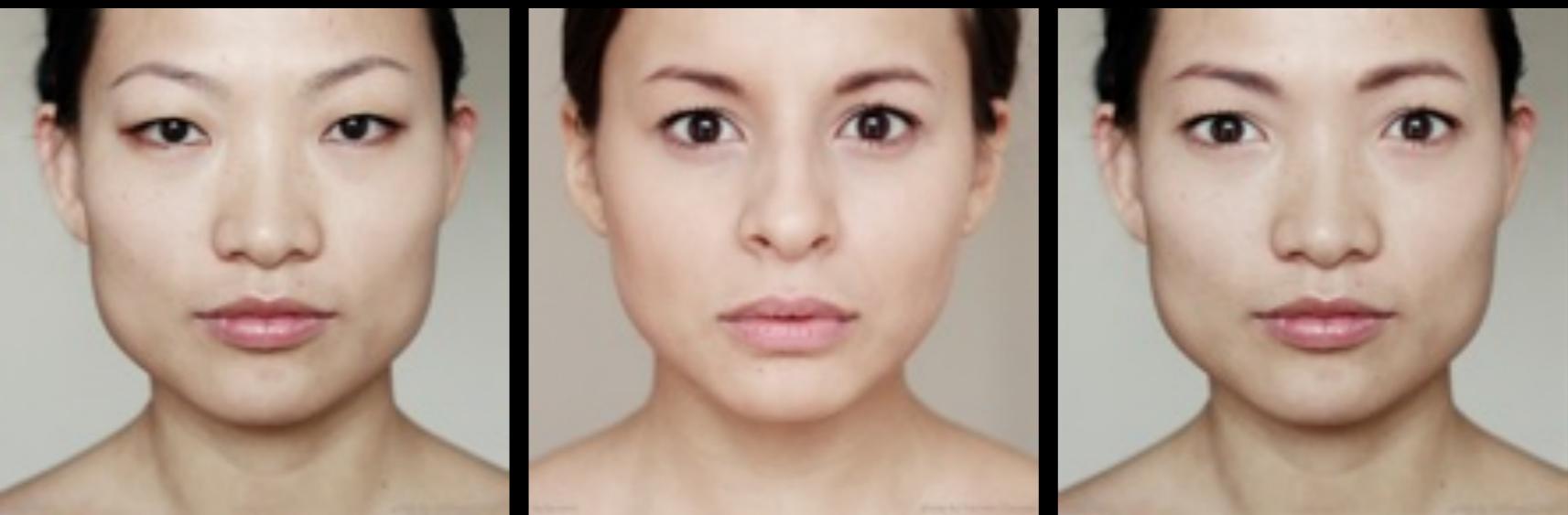
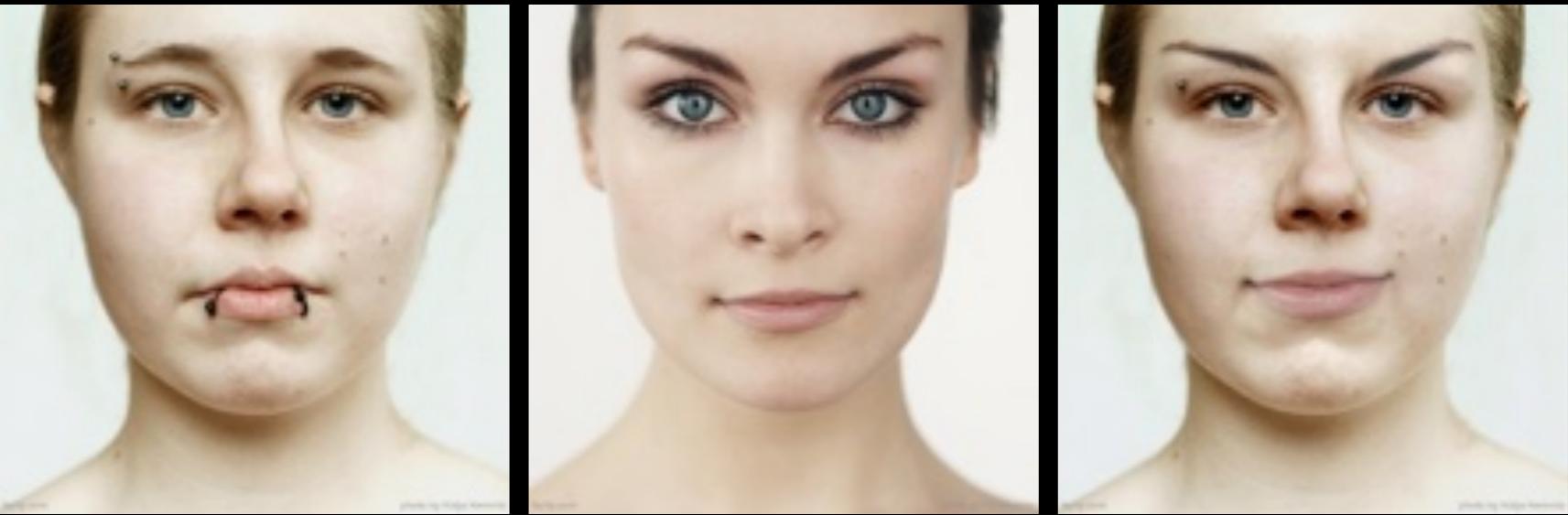
EVOLVING FACES



J. CORREIA, T. MARTINS, P. MARTINS, AND P.
MACHADO, "X-FACES: THE EXPLOIT IS OUT
THERE," ICCC 2016, PP. 164–182.

X-FACES

UNRECOGNIZED FACES



J. CORREIA, T. MARTINS, P. MARTINS, AND P.
MACHADO, "X-FACES: THE EXPLOIT IS OUT
THERE," ICCC 2016, PP. 164-182.

PORTRAITS OF NO ONE

Tiago Martins
João Correia
Sérgio Rebelo
João Bicker
Penousal Machado

Computational Design and Visualization Lab.
CMS / CISUC





Environment of the installation (photo by José Paulo Ruas / DGPC 2019)

Eyebrow



Eyes



Nose



Mouth



Base



Generative process of X-Faces



Portraits of no one



ADVERSARIAL SYSTEMS

ADVERSARIAL LEARNING

CREATE 2 SETS OF IMAGES:

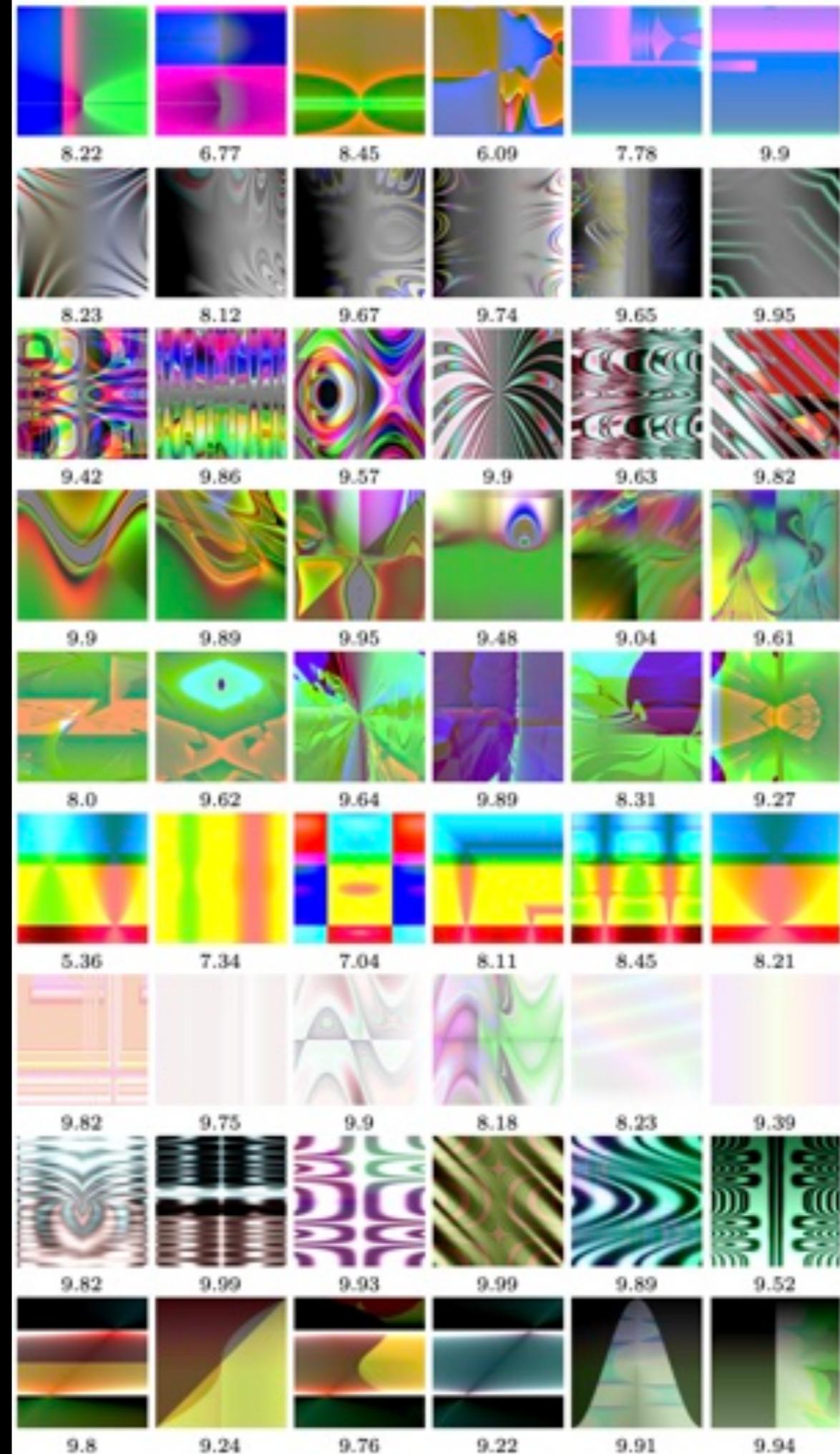
- FAMOUS PAINTINGS
- RANDOMLY GENERATED NEVAR IMAGES.

TRAIN AN ANN TO DISTINGUISH BETWEEN THE TWO SETS.

USE NEVAR TO EVOLVE IMAGES THAT THE ANN CLASSIFIES AS PAINTINGS.

ADD THE EVOLVED IMAGES TO THE TRAINING SET, REPEAT!

P. MACHADO, J. ROMERO, AND B. MANARIS, "EXPERIMENTS IN COMPUTATIONAL AESTHETICS: AN ITERATIVE APPROACH TO STYLISTIC CHANGE IN EVOLUTIONARY ART," IN THE ART OF ARTIFICIAL EVOLUTION: A HANDBOOK ON EVOLUTIONARY ART AND MUSIC, SPRINGER BERLIN HEIDELBERG, 2007, PP. 381-415.



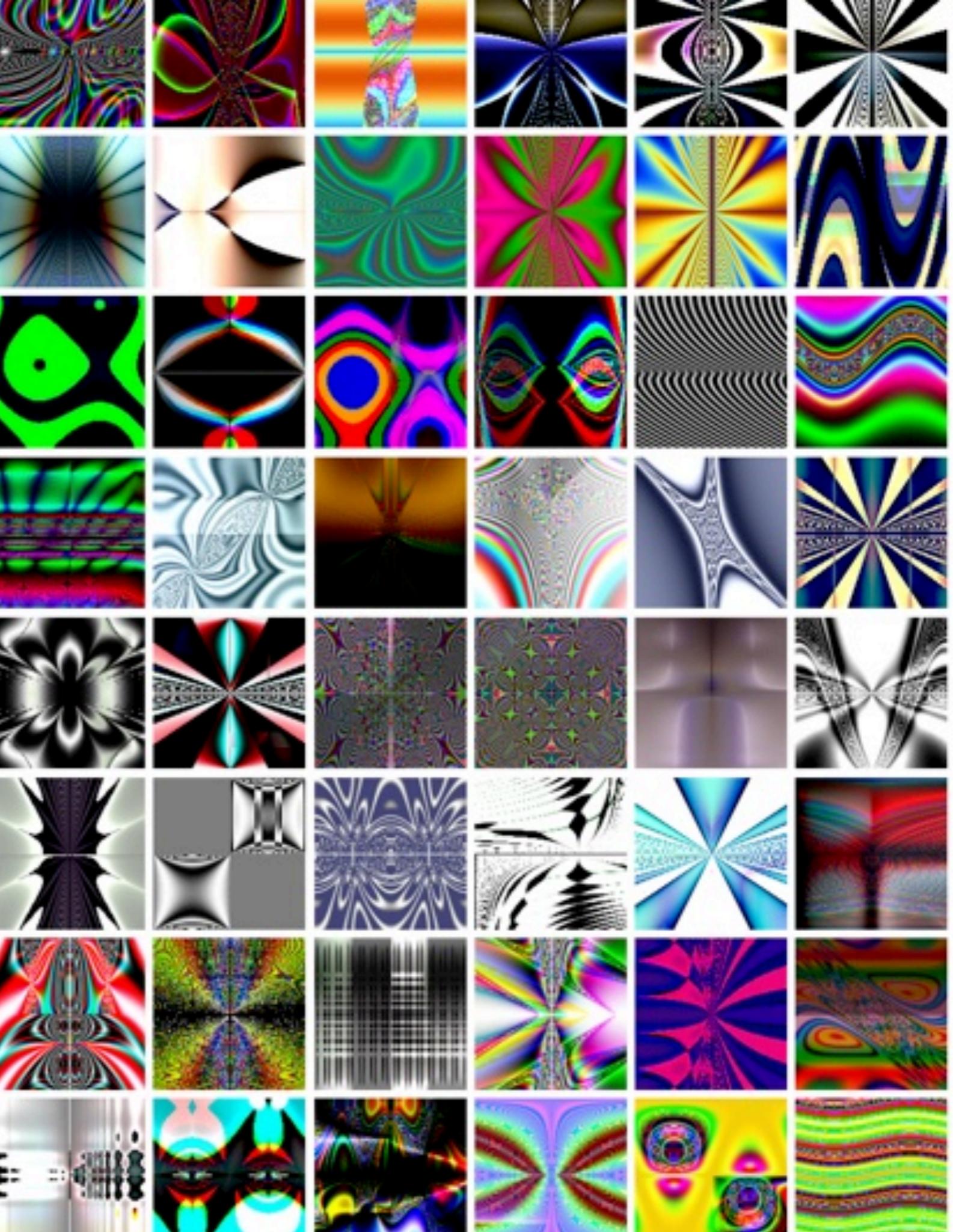
ADVERSARIAL SYSTEMS

SAME BASE IDEA

ARCHIVE

FEASIBLE-UNFEASIBLE EVOLUTIONARY MODEL

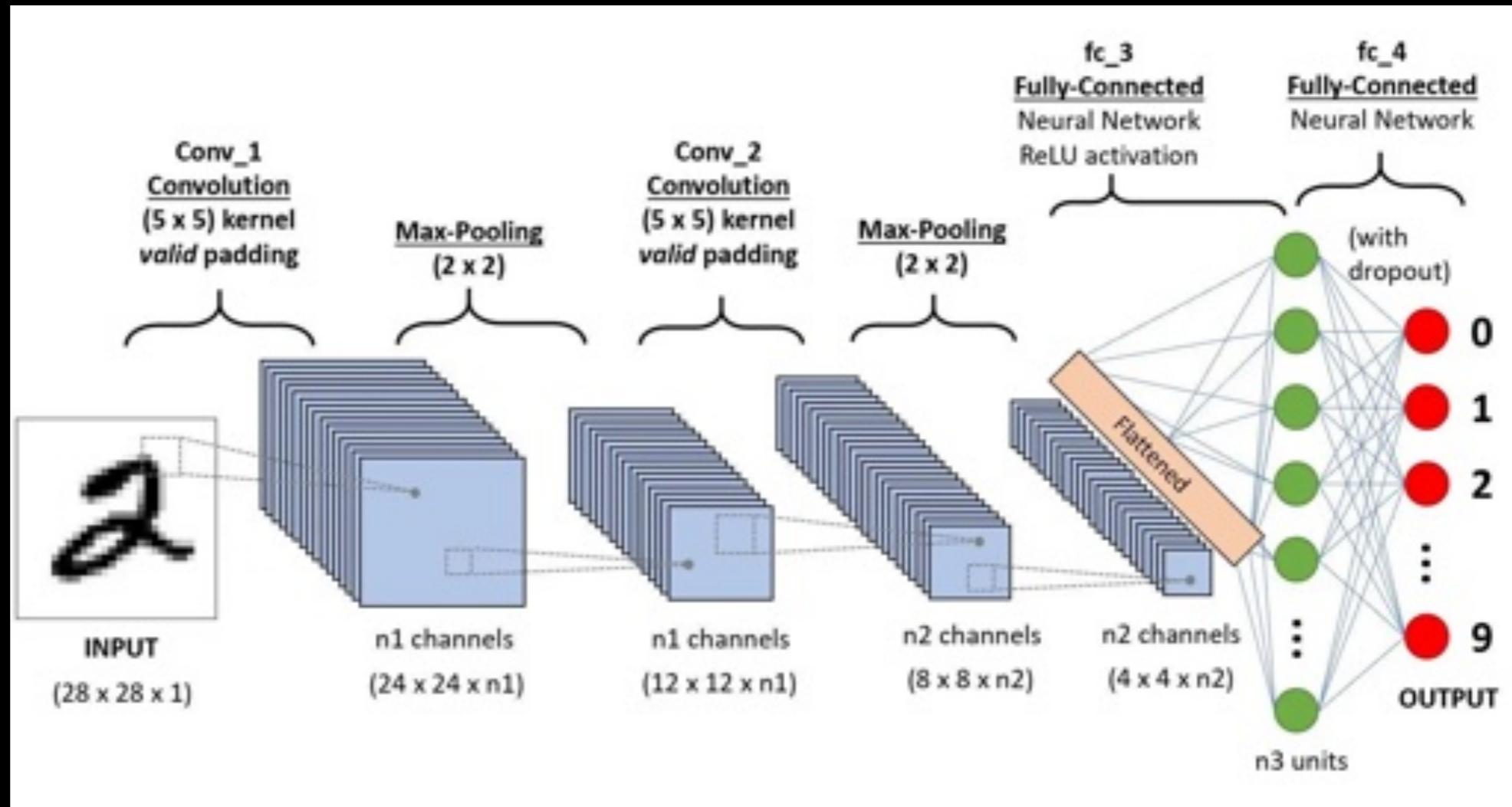
J. CORREIA, P. MACHADO, J. ROMERO, P. MARTINS, AND A. CARDOSO, "BREAKING THE MOULD AN EVOLUTIONARY QUEST FOR INNOVATION THROUGH STYLE CHANGE," IN COMPUTATIONAL CREATIVITY – THE PHILOSOPHY AND ENGINEERING OF AUTONOMOUSLY CREATIVE SYSTEMS, 1 ED., N/A: SPRINGER, 2019, VOL. 1, PP. 353–398.



MACHINE LEARNING

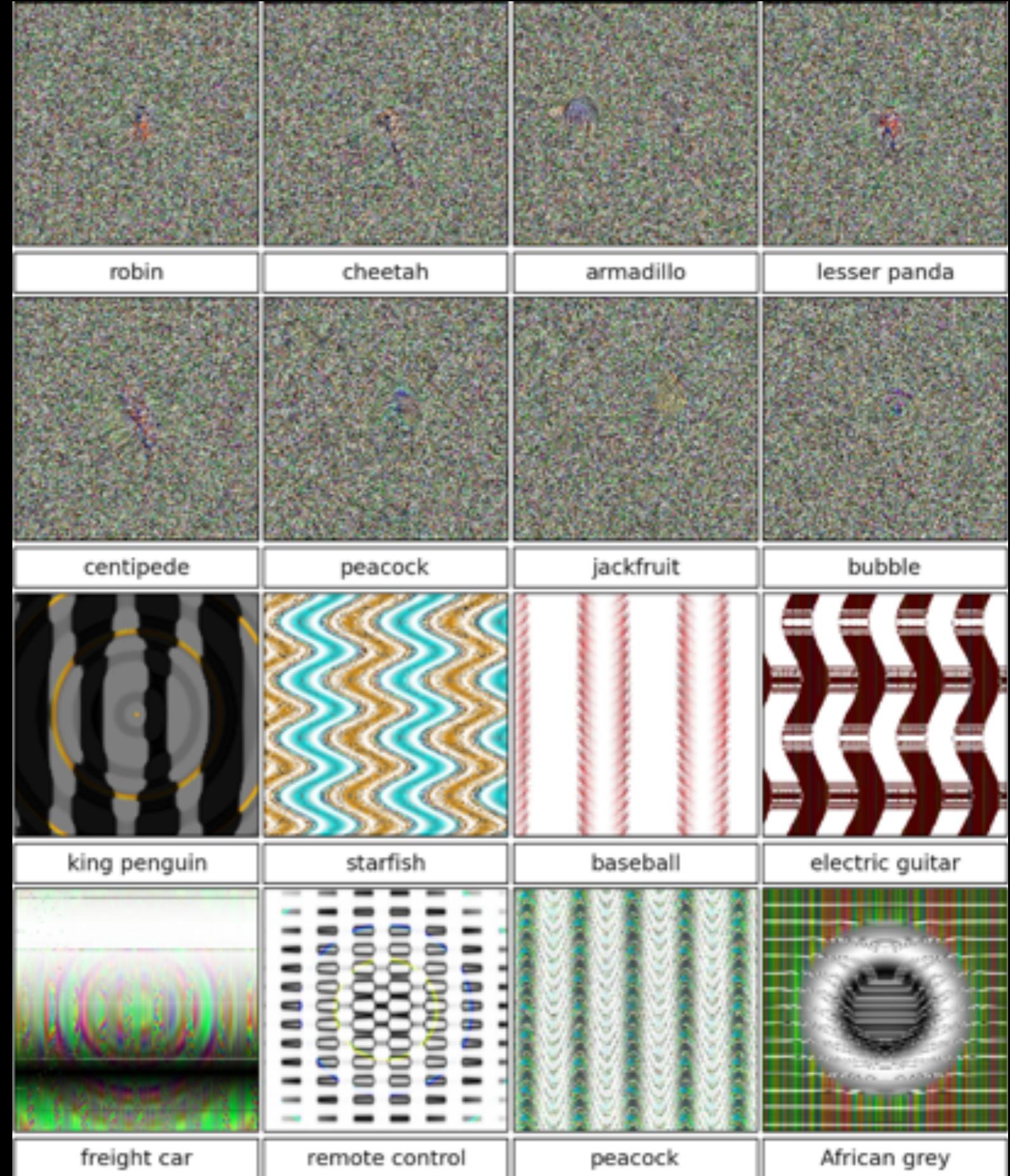
WHY NOT AN CNN ?

TRAINED WITH A LOT
OF DATA?



MACHINE LEARNING

DEEP NEURAL NETWORKS ARE
ALSO EASILY FOOLED



EVOLVING GLYPHS



T. MARTINS, J. CORREIA, E. COSTA, AND P.
MACHADO, "EVOTYPE: FROM SHAPES TO
GLYPHS," GECCO 2016, NEW YORK, NY, USA,
2016, PP. 261-268.

SHAPES

LOAD
SCAN



VIEW

GLYPH GRID
GENETIC INFO X

EVOLVE

SINGLE
BATCH
PAUSE
RESET

EXPORT

GLYPH
TYPEFACE
POSTER

CHARACTERS

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z ALL TEXT

GLYPHS

ALL

GEN 0 > ALL CHARS > RANK 1

MACHINE LEARNING

EVOLVING GLYPHS



T. MARTINS, J. CORREIA, E. COSTA, AND P.
MACHADO, "EVOTYPE: FROM SHAPES TO
GLYPHS," GECCO 2016, NEW YORK, NY, USA,
2016, PP. 261-268.

MACHINE LEARNING

ÄDEA – EVOLVING GLYPHS

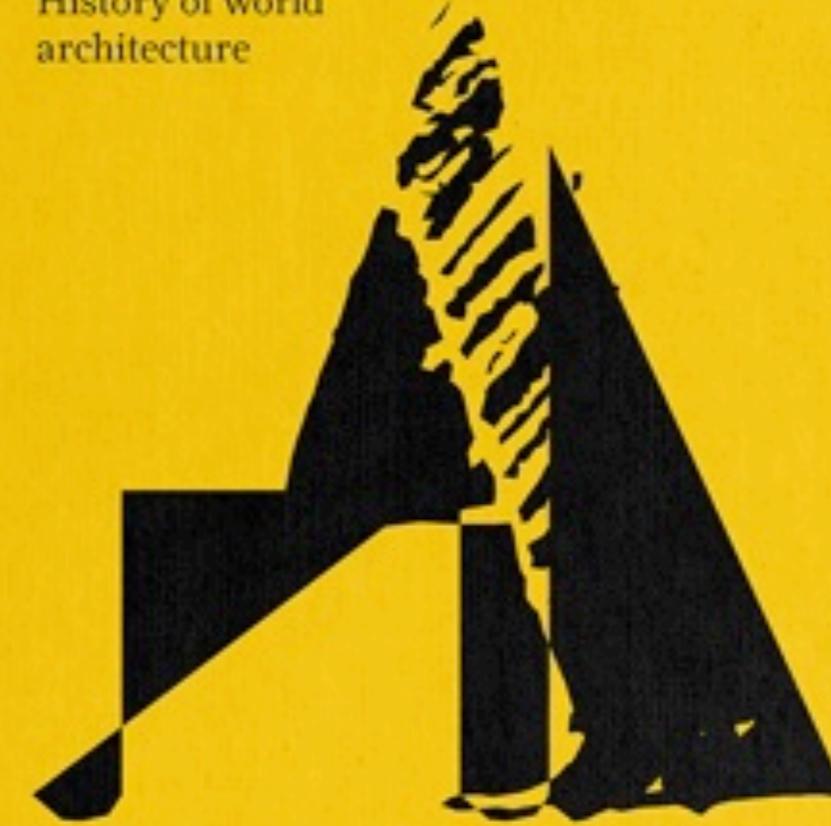
DIRECT MANIPULATION OF SVG GLYPHS

[HTTPS://ADEA.DEI.UC.PT/](https://adea.dei.uc.pt/)

D. LOPES, J. CORREIA, AND P. MACHADO, "ÄDEA –
EVOLVING GLYPHS FOR AIDING CREATIVITY IN TYPEFACE
DESIGN," IN PROCEEDINGS OF THE 2020 GENETIC AND
EVOLUTIONARY COMPUTATION CONFERENCE
COMPANION, NEW YORK, NY, USA, 2020, PP. 97–98.

ANCIENT ARCHITECTURE

History of world
architecture



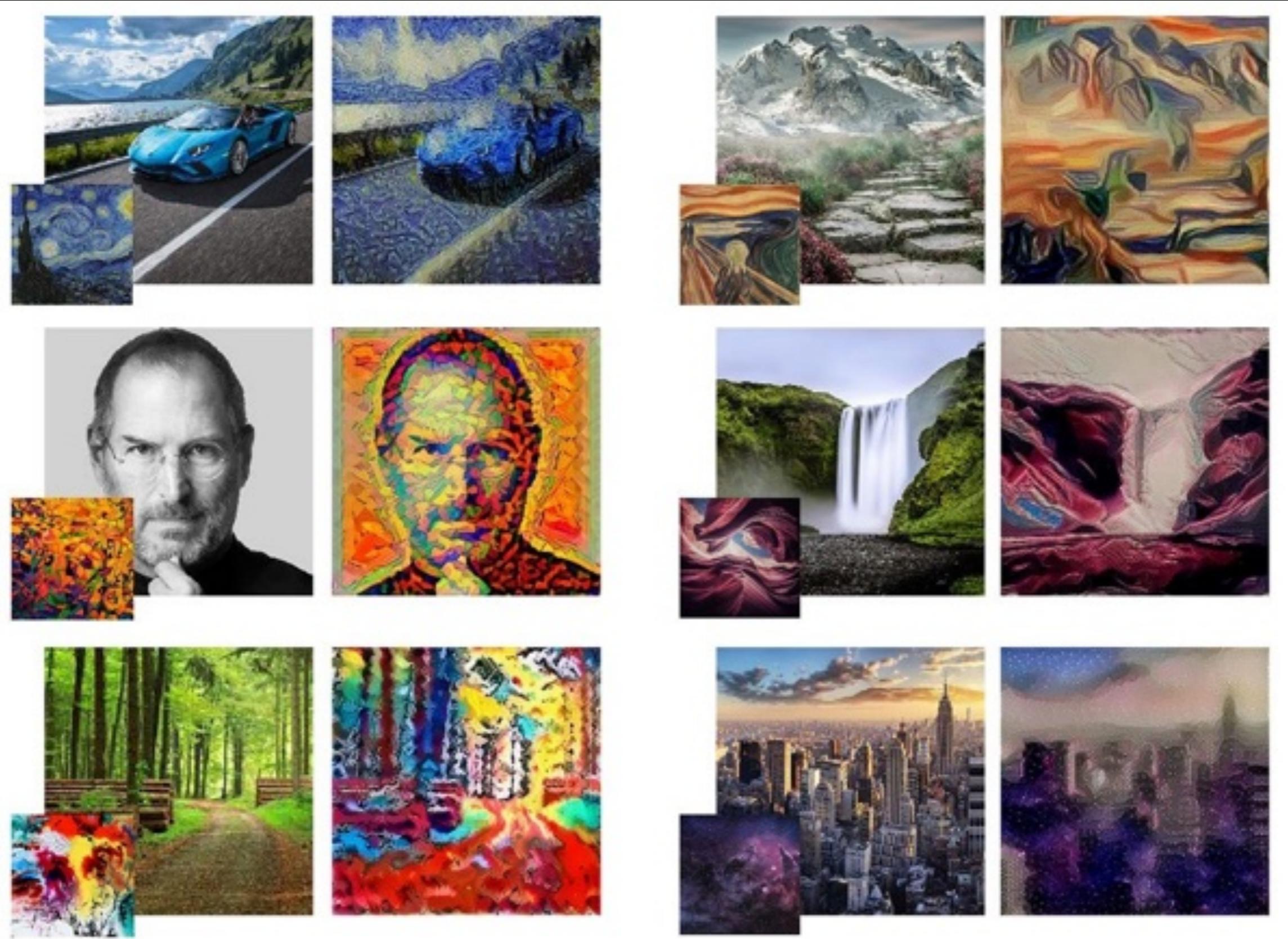
Seton Lloyd
Hans Wolfgang Müller

Machine Learning as Generative Models

MACHINE LEARNING GENERATION – DEEP DREAM



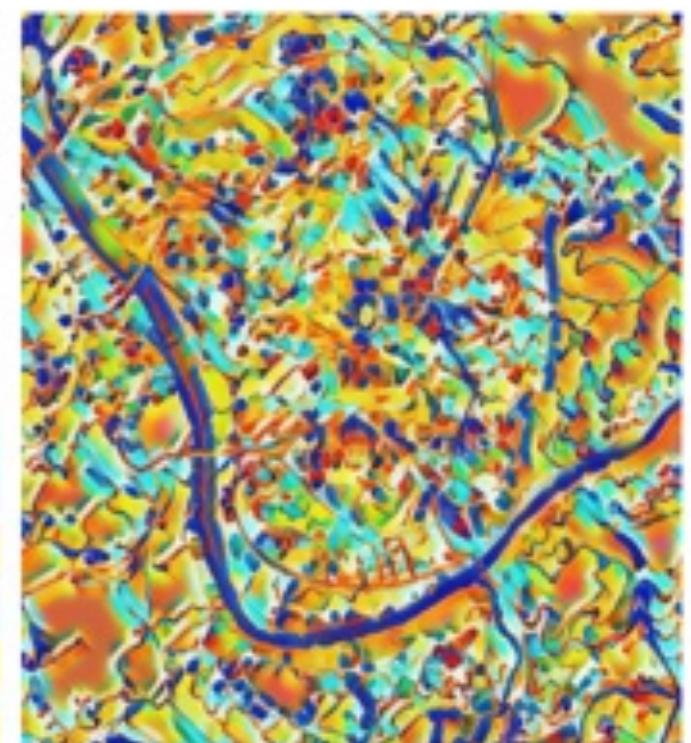
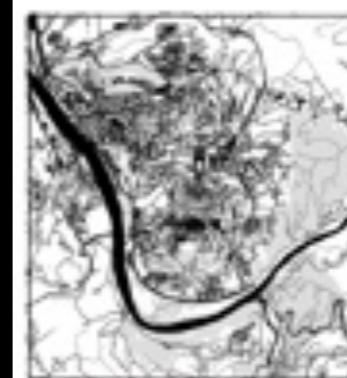
STYLE TRANSFER



Style Transfer

Creating Stylised Maps
with Neural Style
Transfer

<https://cdv.dei.uc.pt/projects/stylised-maps>



GANS

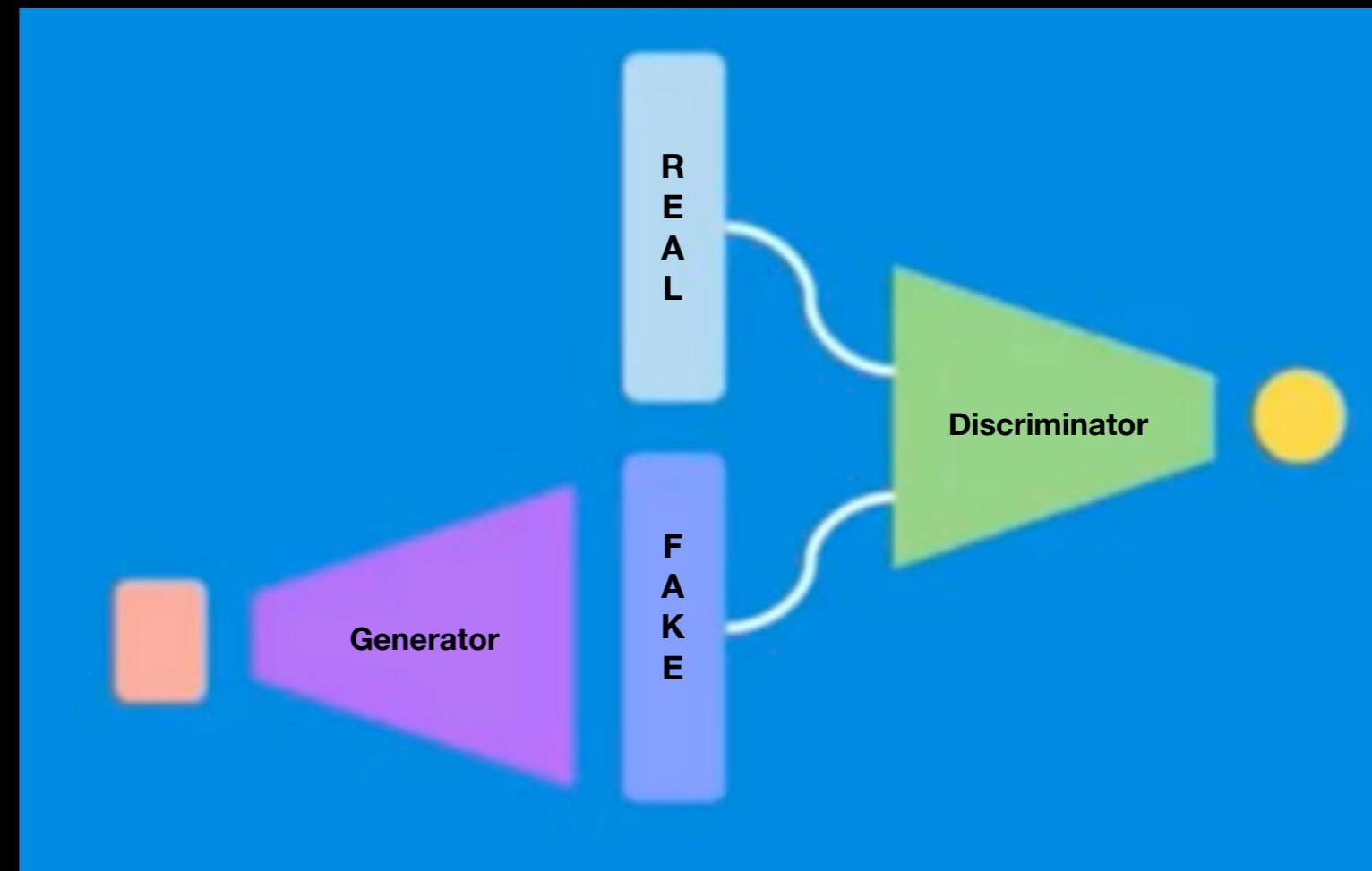


GANs

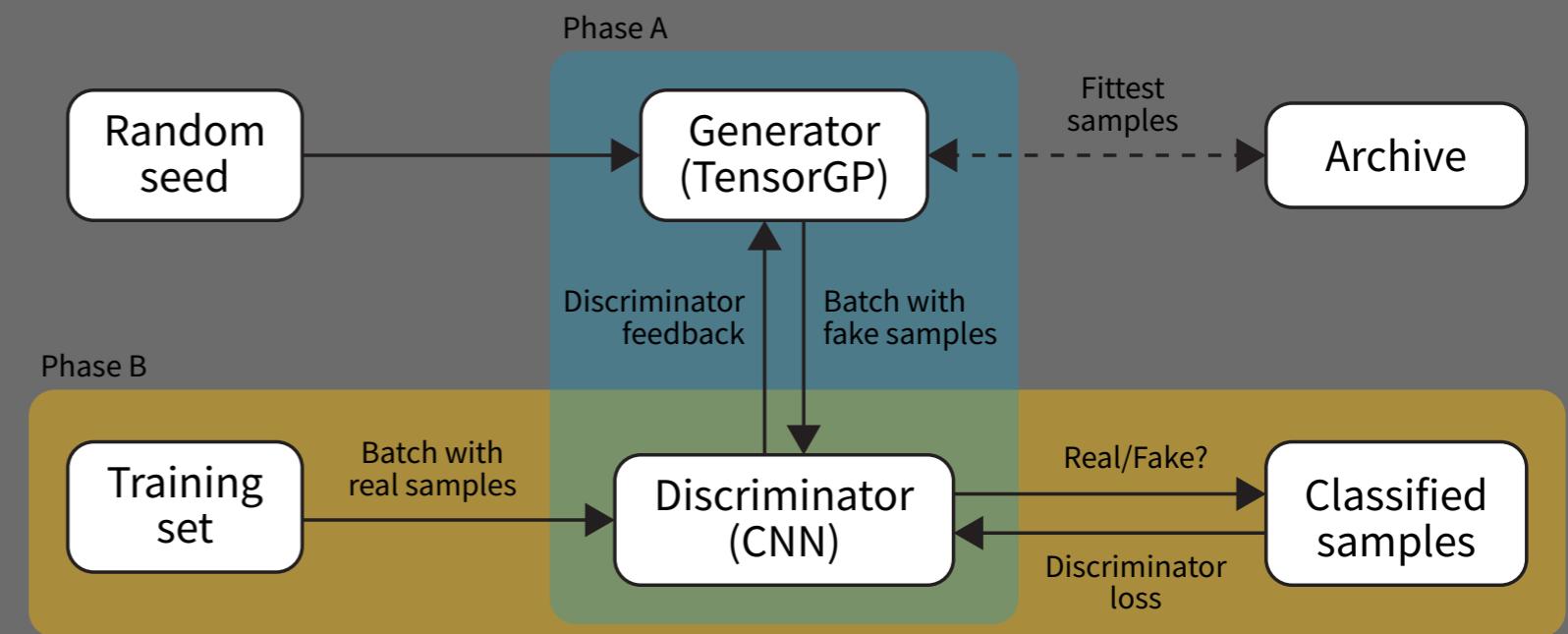
Adversarial Training

Two Neural Networks

What if we change
that?



GP-BASED GENERATIVE ADVERSARIAL MODELS

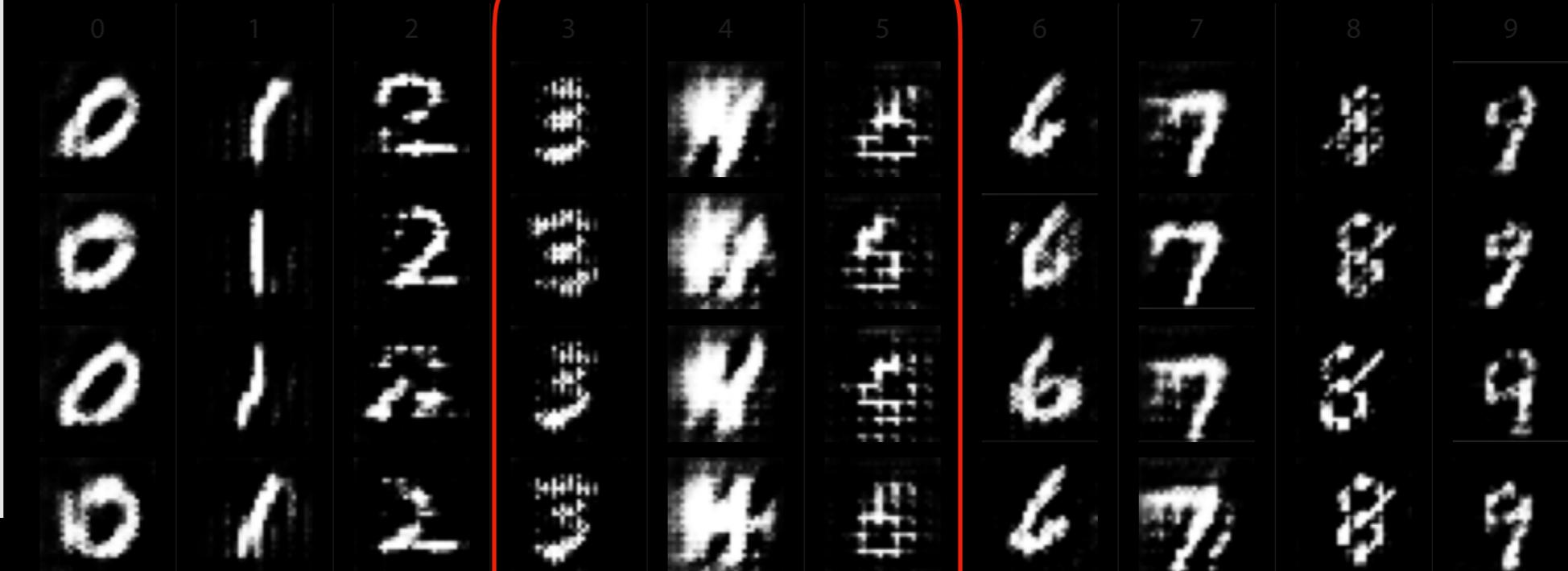


P. Machado, F. Baeta, T. Martins,
and J. Correia, “GP-Based
Generative Adversarial
Models,” in *Genetic Programming
Theory and Practice XIX*, 2023, pp.

TGPGAN
Images



DCGAN



**CLIP +
BIGGAN+
CMA-ES+
ADAM+
T-SNE+
?**

A PAINTING OF SUPERMAN BY VAN GOGH

V. COSTA, N. LOURENÇO, J. CORREIA, AND P.
MACHADO, "EXPLORING GENERATIVE
ADVERSARIAL NETWORKS FOR TEXT-TO-
IMAGE GENERATION WITH EVOLUTION
STRATEGIES," IN COMPANION PROCEEDINGS OF
THE CONFERENCE ON GENETIC AND
EVOLUTIONARY COMPUTATION, GECCO 2023,
COMPANION VOLUME, LISBON, PORTUGAL,
JULY 15-19, 2023, 2023, PP. 271-274.

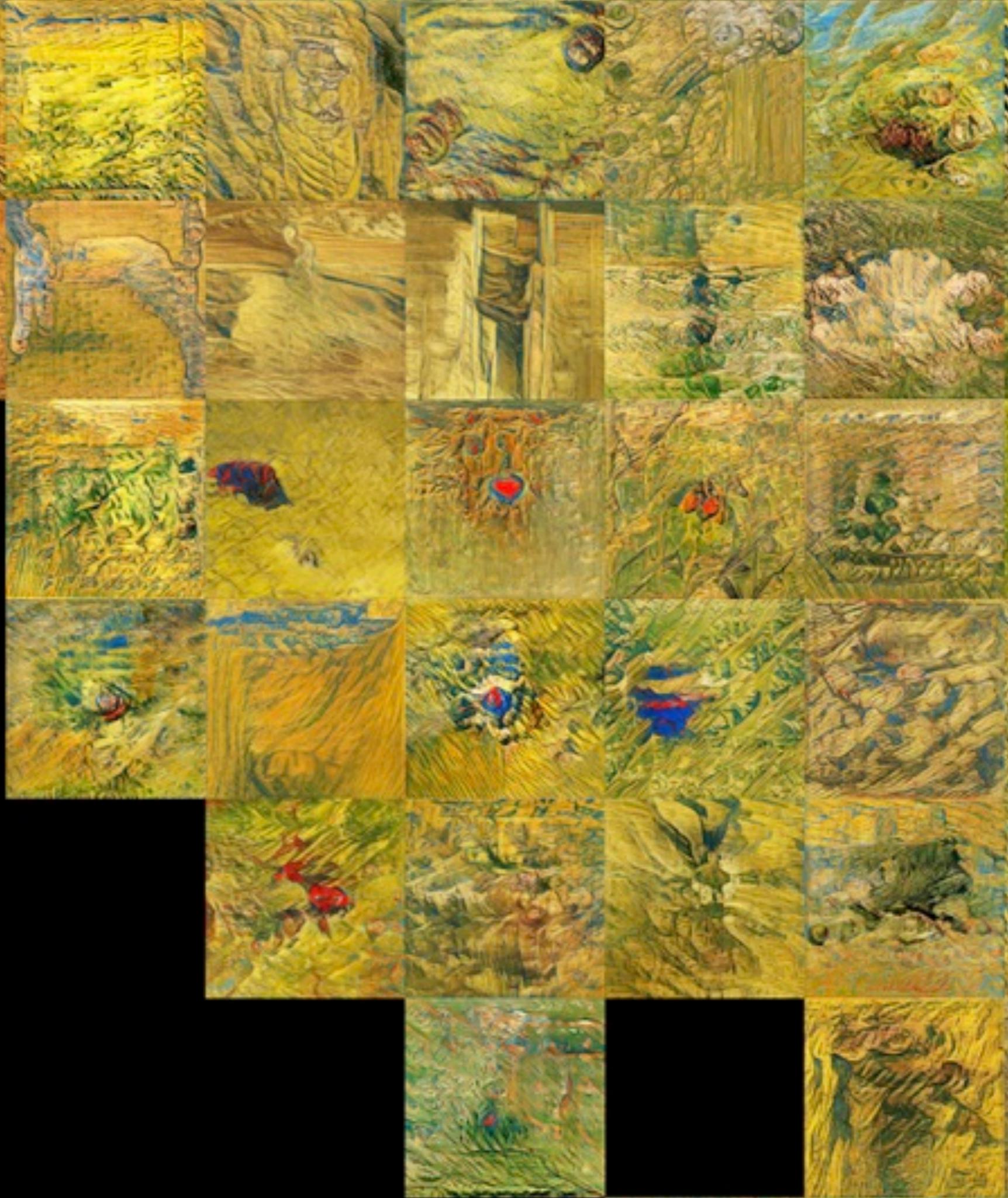


WITHOUT EVOLUTION

V. COSTA, N. LOURENÇO, J. CORREIA, AND P. MACHADO, "EXPLORING GENERATIVE ADVERSARIAL NETWORKS FOR TEXT-TO-IMAGE GENERATION WITH EVOLUTION STRATEGIES," IN COMPANION PROCEEDINGS OF THE CONFERENCE ON GENETIC AND EVOLUTIONARY COMPUTATION, GECCO 2023, COMPANION VOLUME, LISBON, PORTUGAL, JULY 15-19, 2023, 2023, PP. 271-274.

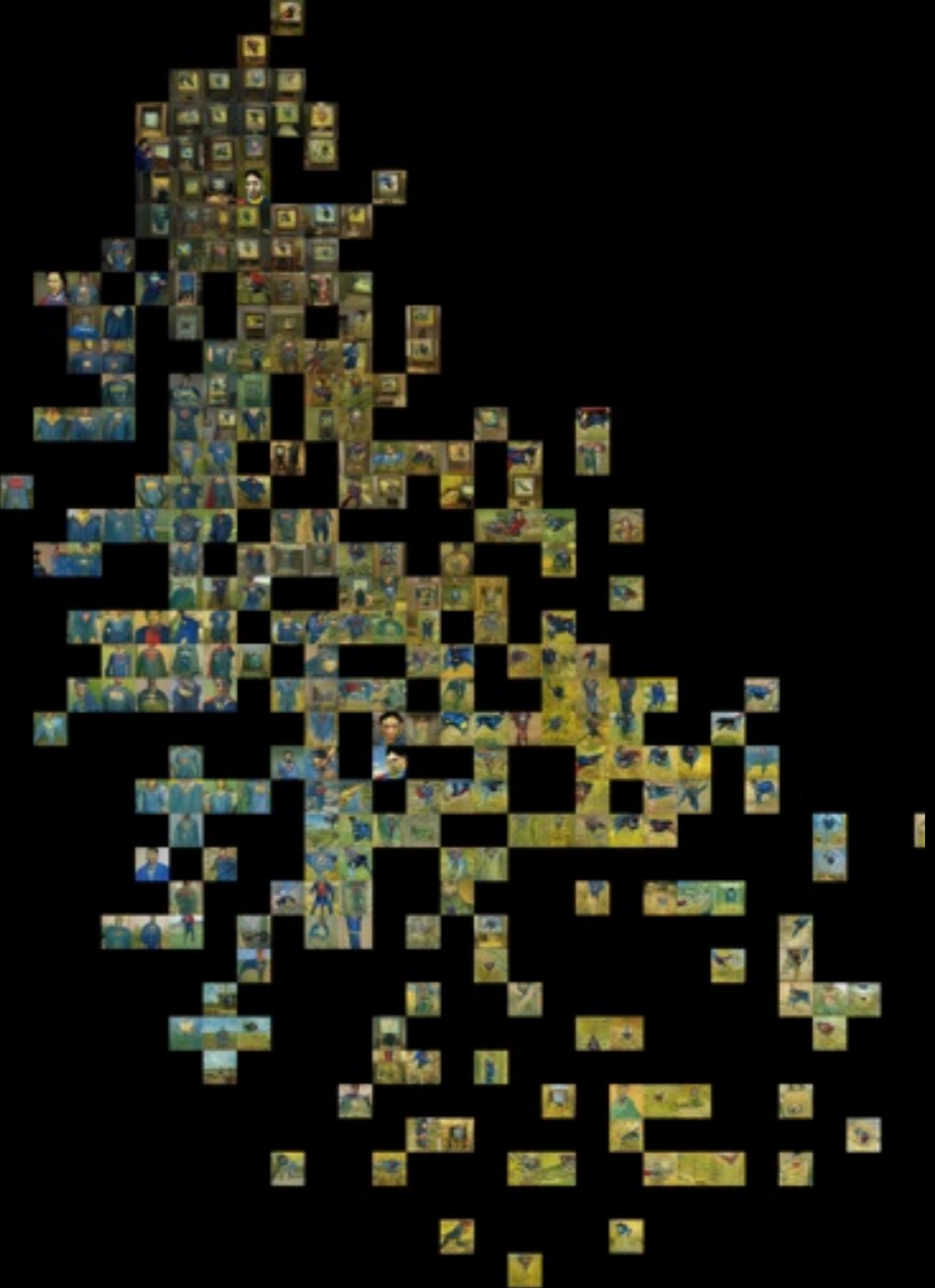


WITHOUT EVOLUTION



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EVOLUTION



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WITH EVOLUTION



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JULY 15-19, 2023, 2023, PP. 271-274.

WITH EVOLUTION

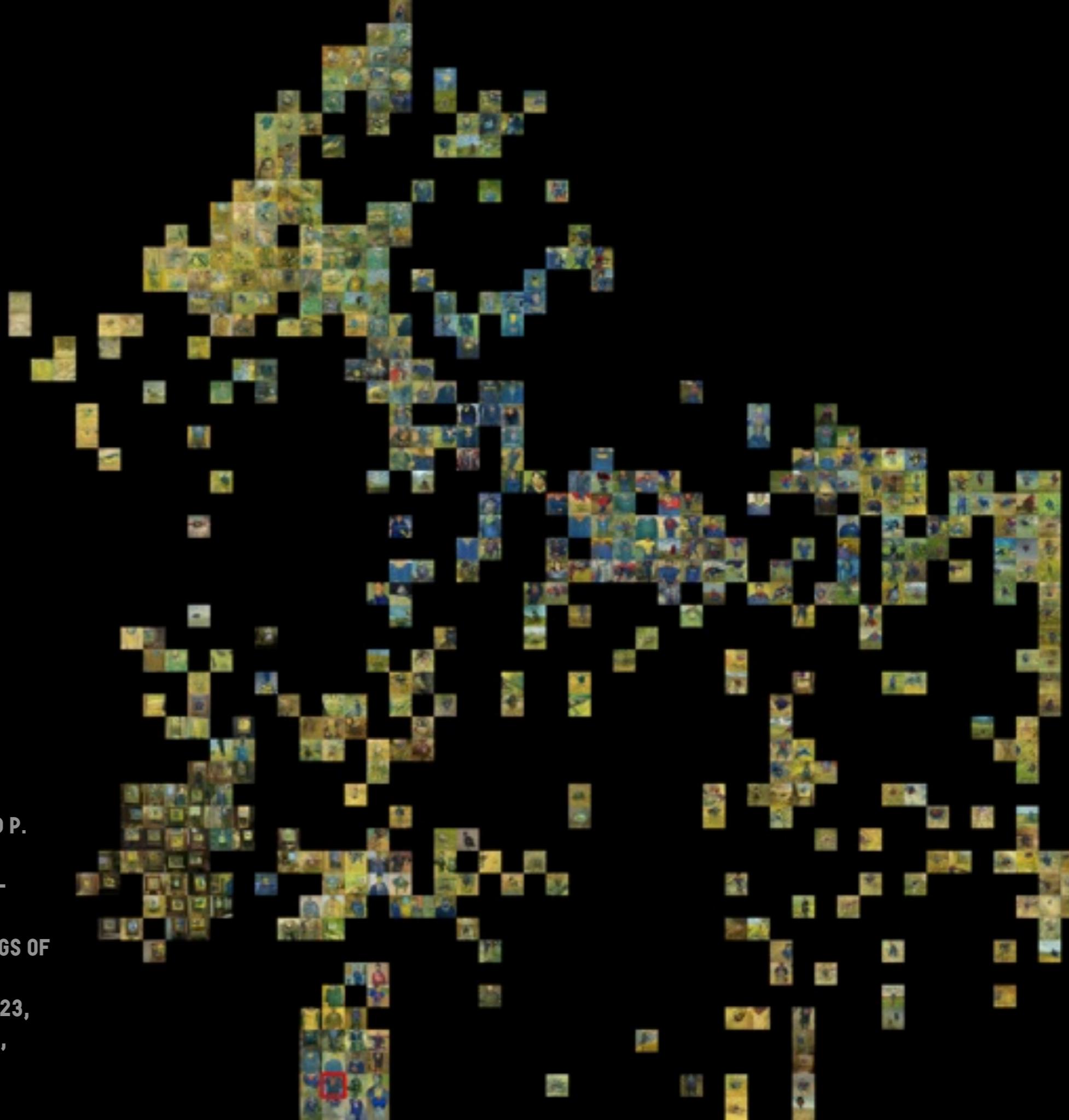


V. COSTA, N. LOURENÇO, J. CORREIA, AND P. MACHADO, "EXPLORING GENERATIVE ADVERSARIAL NETWORKS FOR TEXT-TO-IMAGE GENERATION WITH EVOLUTION STRATEGIES," IN COMPANION PROCEEDINGS OF THE CONFERENCE ON GENETIC AND EVOLUTIONARY COMPUTATION, GECCO 2023, COMPANION VOLUME, LISBON, PORTUGAL, JULY 15-19, 2023, 2023, PP. 271-274.



EVOLUTION GUIDED BY T-SNE

V. COSTA, N. LOURENÇO, J. CORREIA, AND P.
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JULY 15-19, 2023, 2023, PP. 271-274.



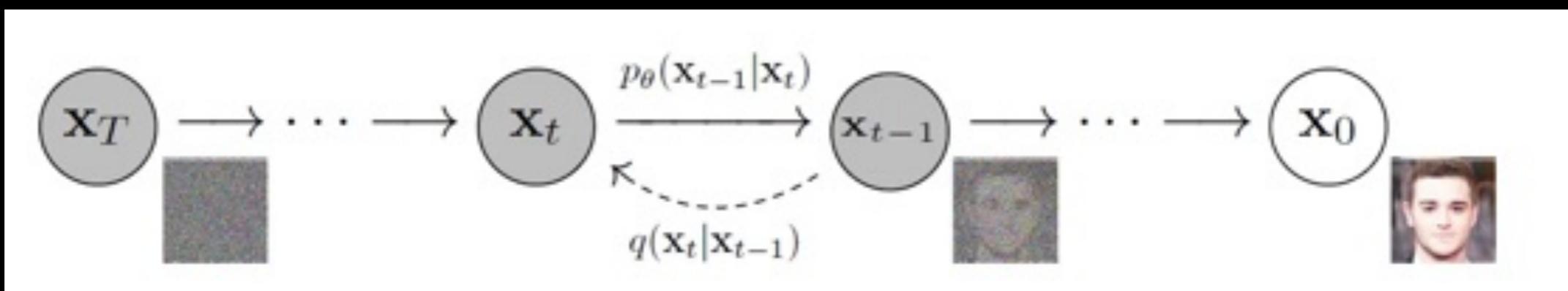
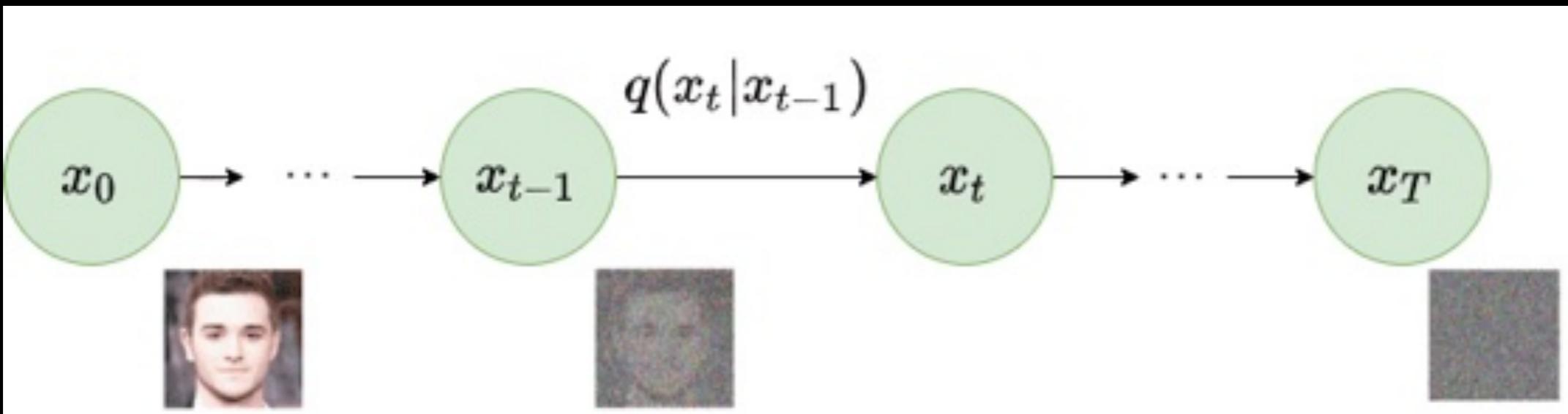
EVOLUTION GUIDED BY T-SNE



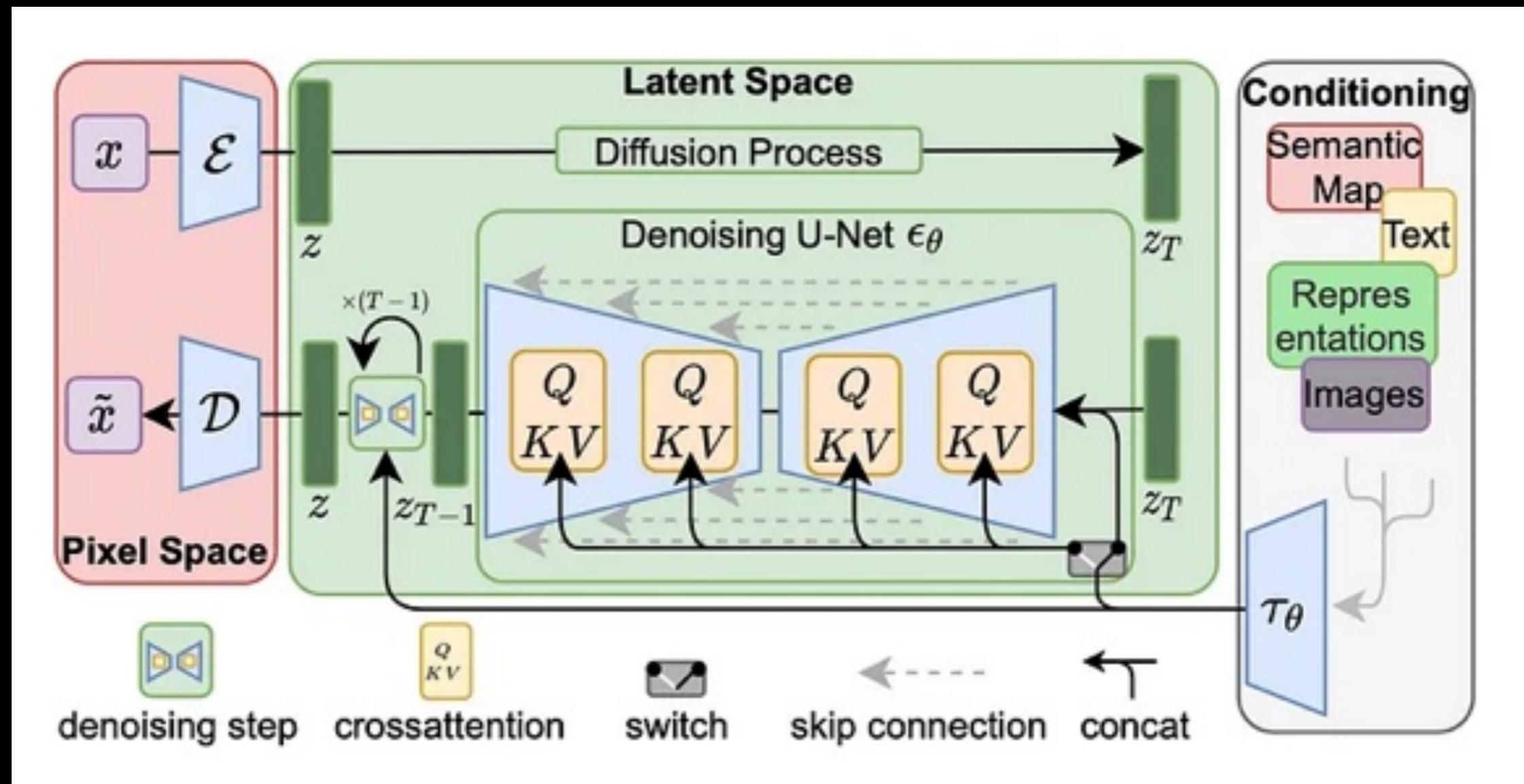
Diffusion Models



Diffusion Models

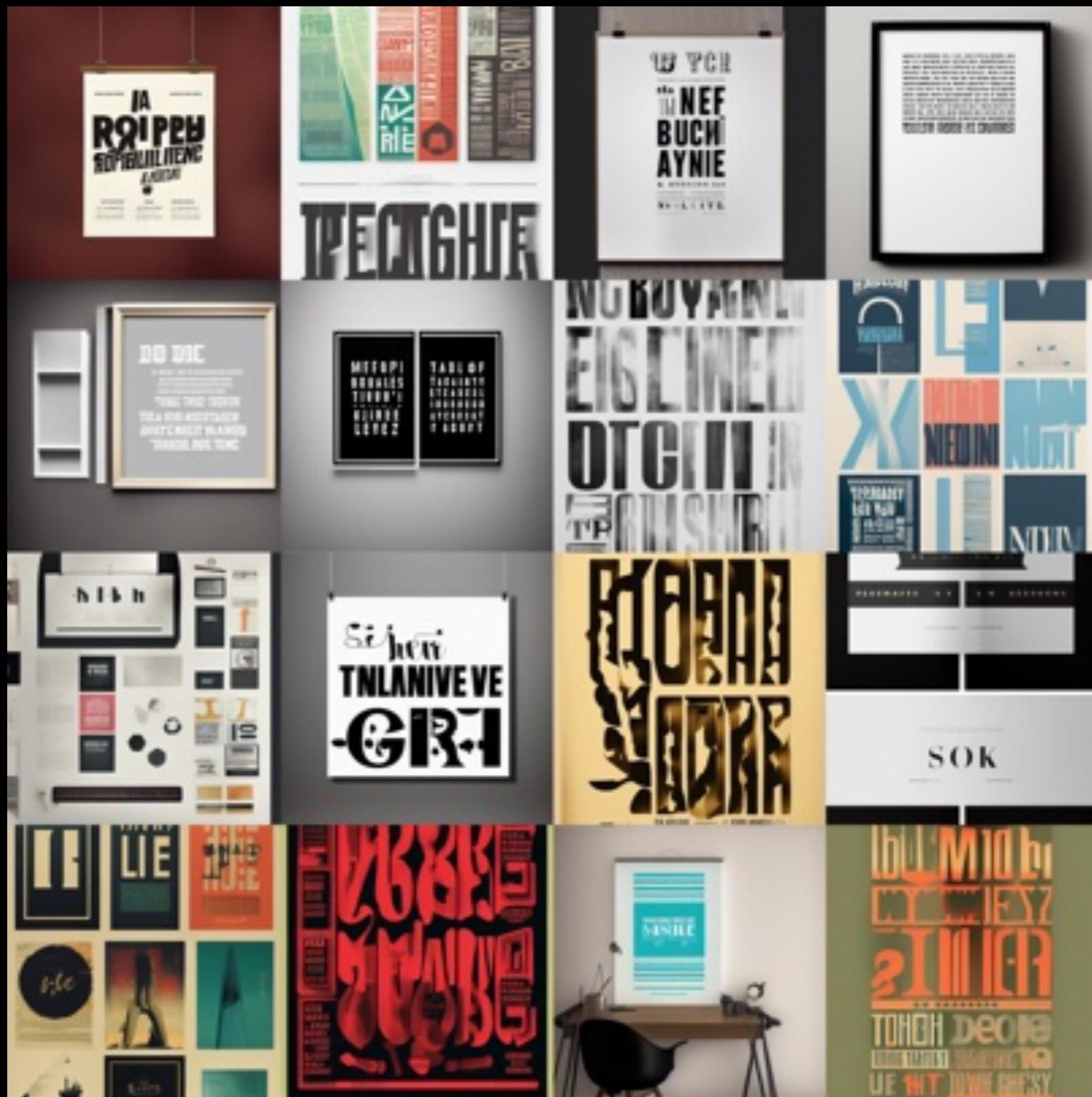


Latent Diffusion Models



Latent Diffusion Models

Stable diffusion models



EVOLUTIONARY MACHINE LEARNING

METAPROMPTER

PROMPT EVOLUTION



A beautiful painting of a singular lighthouse, shining its light across a tumultuous sea of blood by greg rutkowski and thomas kinkade, Trending on artstation.



woman in the
glitch art
style



woman in the
Cubism art style



woman in the
Andean textile
style

Prompt templates examples

[Subject] in the style of [Style]

Liu and Chilton (2022)

[Medium] [Subject] [Artist(s)] [Details] [Image repository support]

Oppenlaender (2022)

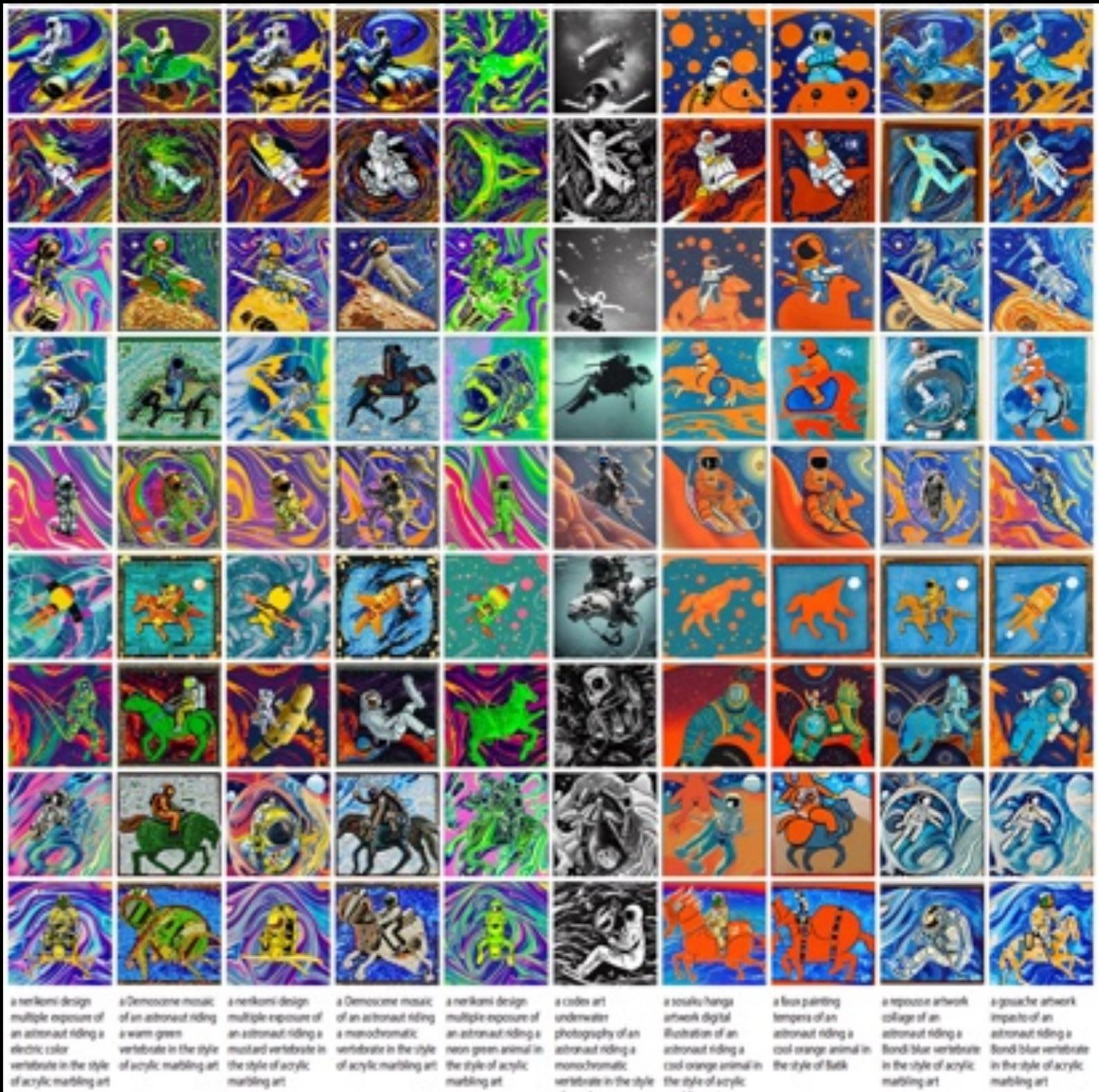
[Subject], by [Artist] (and [Artist]), [Modifier(s)], ...

Smith (2023)

EVOLUTIONARY MACHINE LEARNING

METAPROMPTER

PROMPT EVOLUTION



A COIN DESIGNED BY AI

MULTIPLE SYSTEMS (MULTIMODAL)

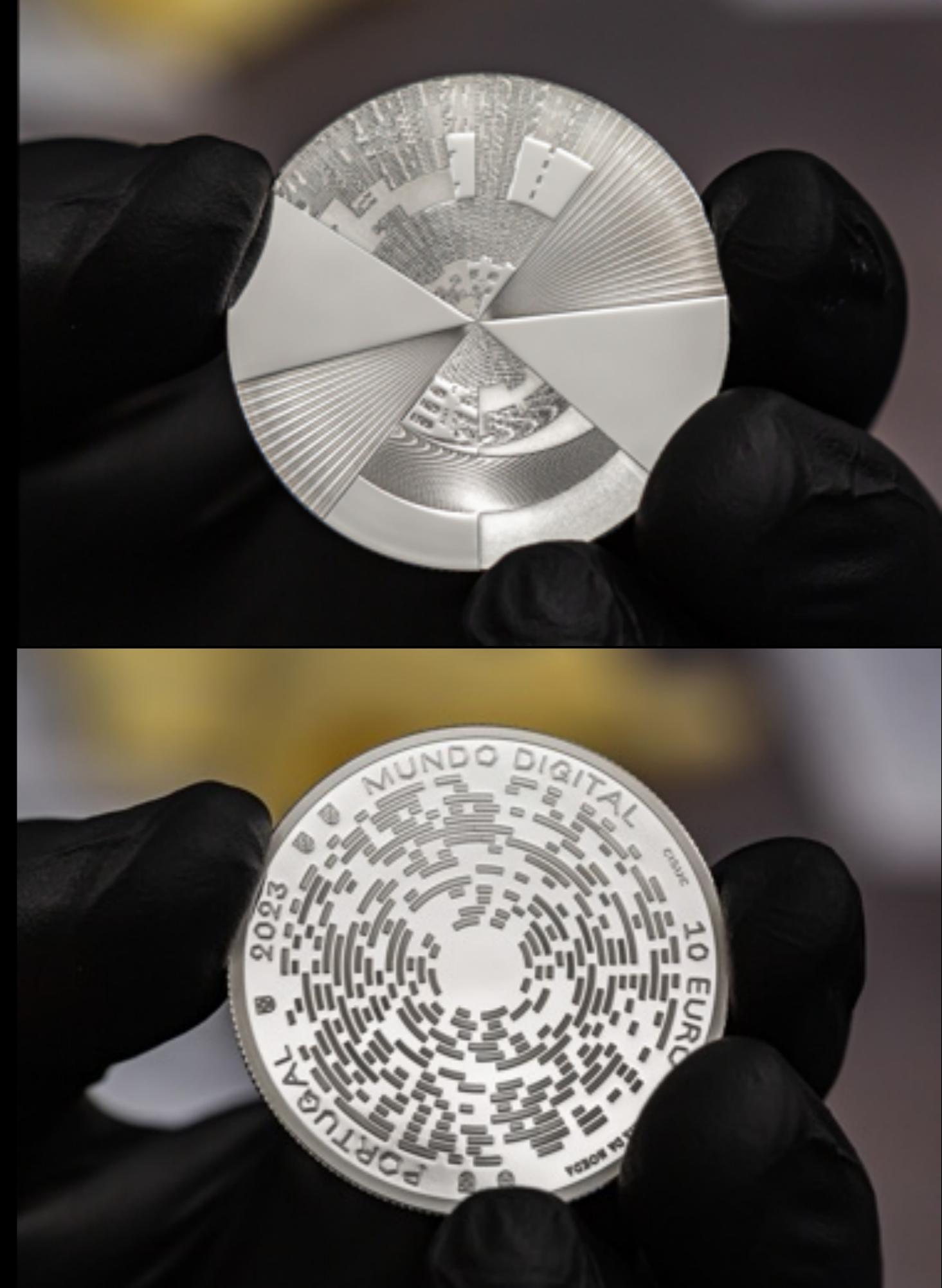
REVERSE OF THE COIN

METAPROMPTER ON STABLE DIFFUSION

TENSORGP + CLIP + BIGGAN

OBVERSE

GENERATIVE SYSTEM ENCODING THE REVERSE



MultiModal ML

LLMs based



 OpenAI
 GPT-4

MultiModal ML

Text (conversation) + Image (Dall-E)



MultiModal ML

SORA - Text (conversation) + Video

Creating video from text

Sora is an AI model that can create realistic and imaginative scenes from text instructions.

[Read technical report](#)



Conclusion

Deep Learning for Visual Arts

- Exciting ERA for Deep Learning in Visual Arts via Generative (AI) Models
- Deep Learning Models being key
- Other Synergies occurring



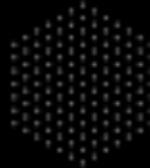
Deep Learning for Visual Arts

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FACULDADE DE
CIÉNCIAS E TECNOLOGIA
UNIVERSIDADE DE
COIMBRA



COMPUTATIONAL
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