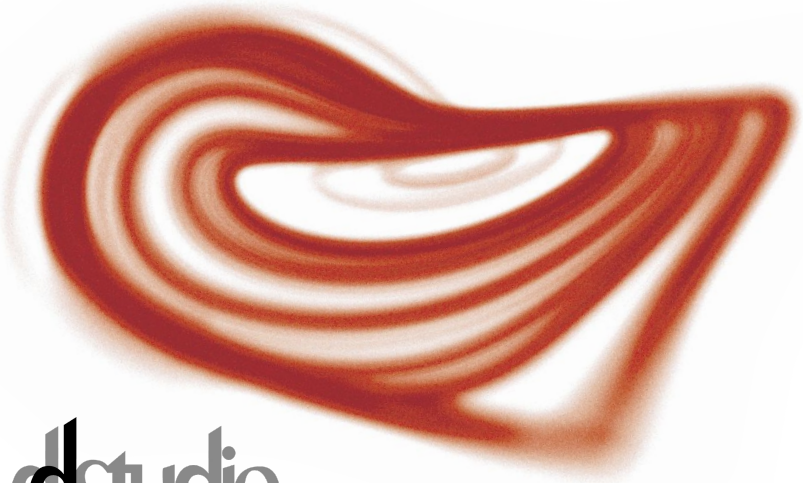


BS723

Machine Learning Applications in Architecture

CONTINUOUS MERGING OF STRANGE ATTRACTORS

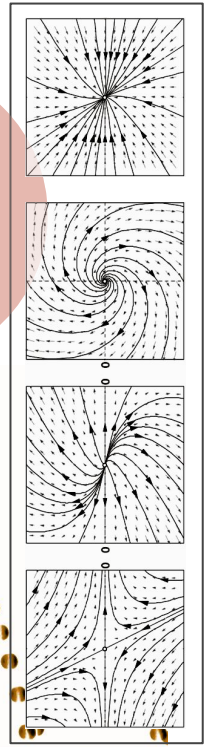
using evolutionary algorithm

dstudio
DIGITAL DESIGN STUDIO

Ozgur Gulsuna ozgur.gulsuna@metu.edu.tr

DYNAMICAL SYSTEMS

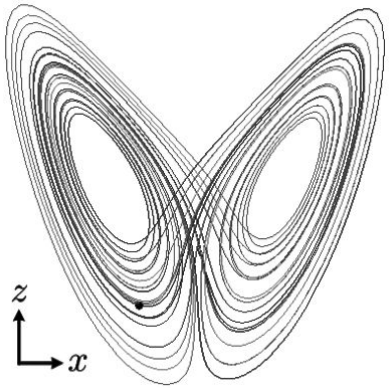
In mathematics, a dynamical system describes the **time-dependent** behavior of a point in space using a function.

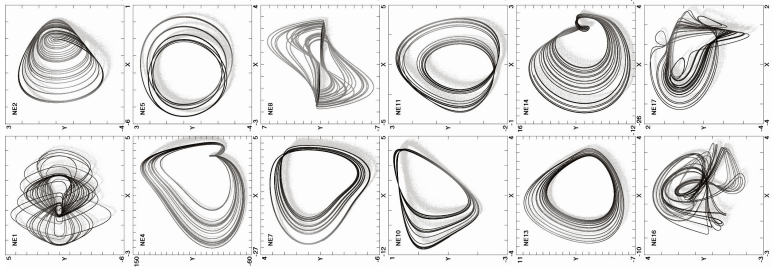


$$\frac{\mathrm{d}x}{\mathrm{d}t} = \sigma(y - x),$$

$$\frac{\mathrm{d}y}{\mathrm{d}t} = x(\rho - z) - y,$$

$$\frac{\mathrm{d}z}{\mathrm{d}t} = xy - \beta z.$$



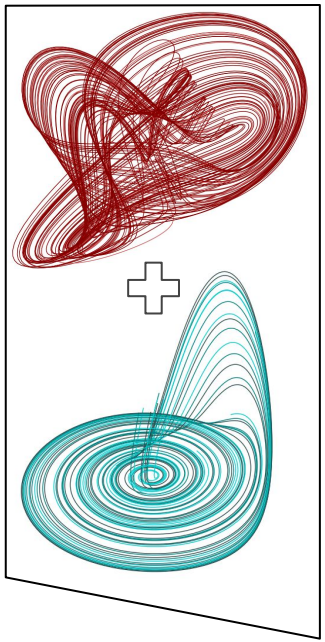


Find/Create a new system

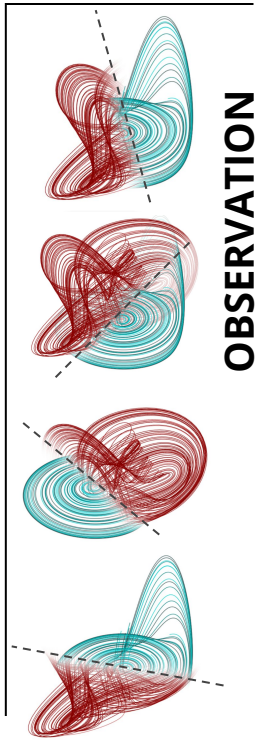
Find: Exploration in vast possibilities
Create: Combining systems together

FORM

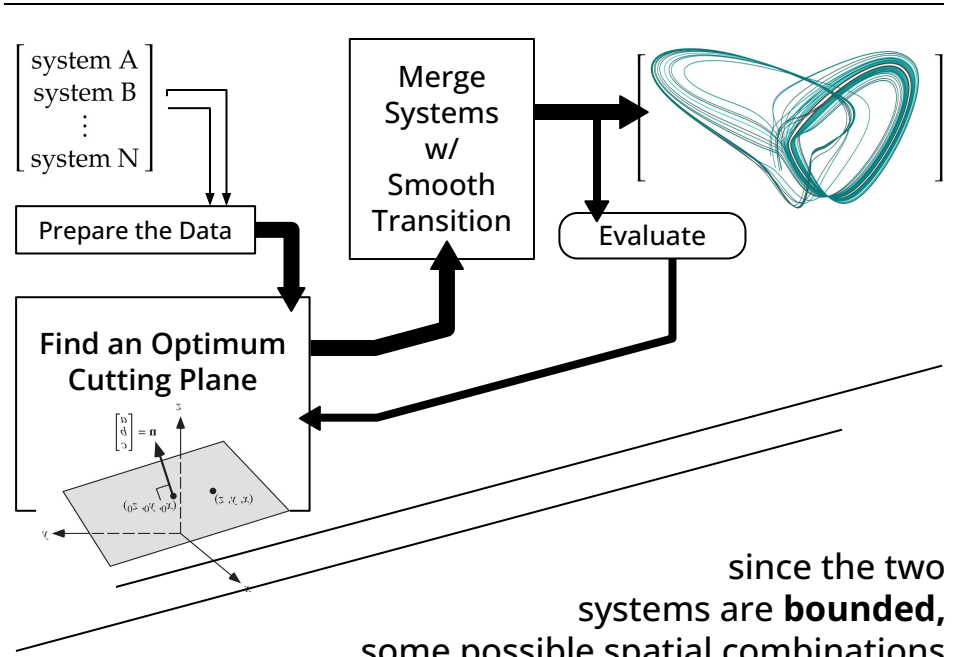
PROBLEM DEFINITION



MATERIAL



OBSERVATION

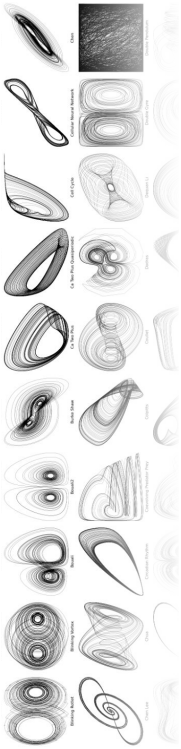


MODEL

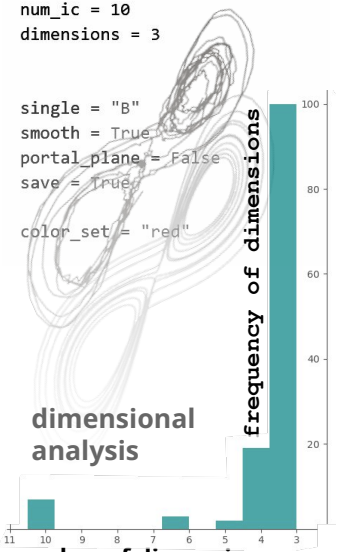
since the two systems are **bounded,** some possible spatial combinations can also be bounded, and perhaps **chaotic.**

DATA PREPARATION

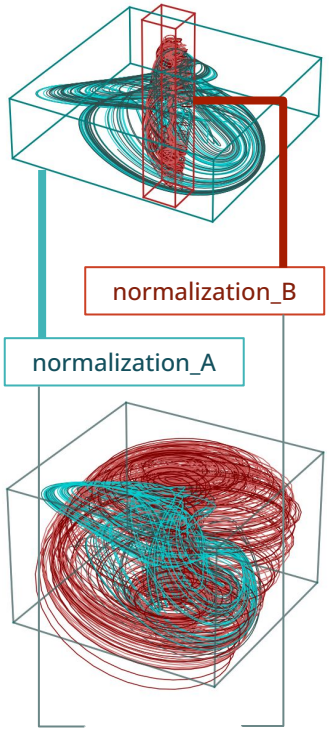
```
setup(name = 'dysts',
    # More than a hundred strange attractors
    # https://github.com/williamgilpin/dysts
    packages=['dysts'],
    version='0.1',
```



```
# Parameters ==================

dt = 0.01
t = np.arange(0, dt*800*2, dt)

system_A = "Halvorsen"
system_B = "QiChen"

num_ic = 10
dimensions = 3

single = "B"
smooth = True
portal_plane = False
save = True

color_set = "red"
```

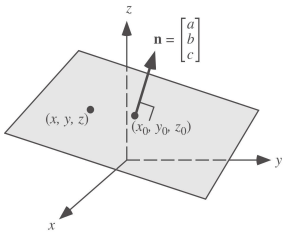


number of dimensions



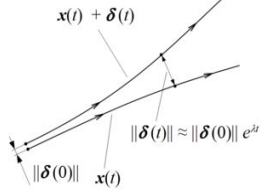
UNIFORM

```
================ Transformations #

        r = random_rotation()
    theta = random_rotation()
      phi = random_rotation()

a,b,c,d = rotate(r,phi,theta)

plane = create_plane(a,b,c,d)

if point(x,y,z) > plane:
      sys = "A"

if point(x,y,z) < plane:
      sys = "B"
```



more planes, more regions

lyapunov exponent

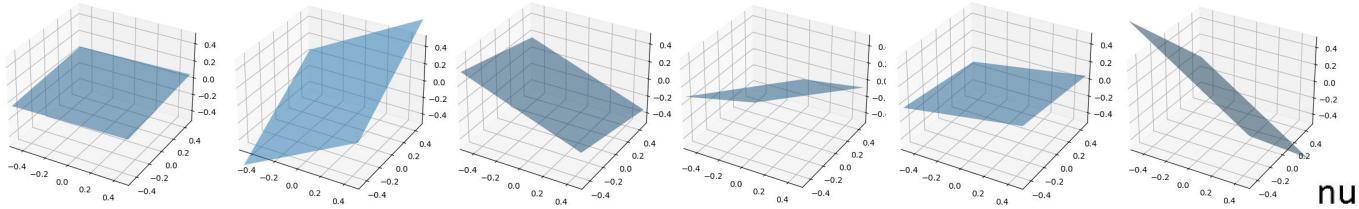



```
"maximum_lyapunov_estimated": 4.0

"kaplan_yorke_dimension": 2.09174

"lyapunov_spectrum_estimated": [
    3.8880075026301206,
    0.13379585631170307,
    -43.8359895934497
],

"multiscale_entropy": 0.846453868

"pesin_entropy": 4.02180335894182
```

EVALUATION

MODEL SELECTION

evolutionary algorithm

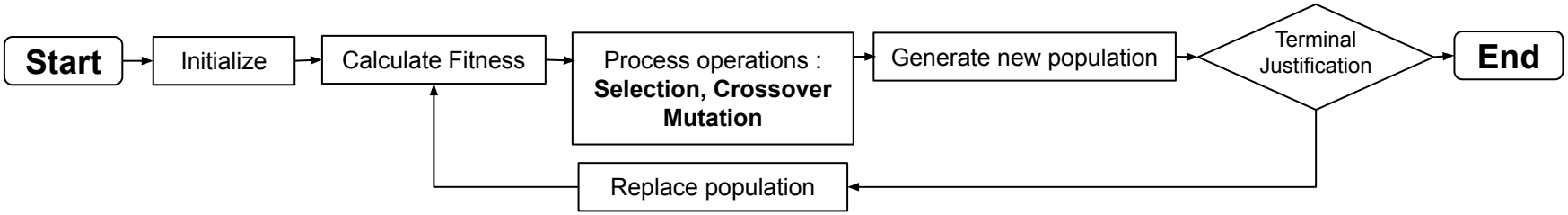


```
num_inds = 20
num_genes = 1
num_generations = 50
```

Individual: a solution candidate, which is a plane hence, has one gene and a fitness value.
Gene: consist of phenotypes of the individual, for our case rotation (r, theta, phi).
Population: a group of individuals to be selected, reproduced and mutated.

- **Elites:** partition of population which are directly moved to the next generation.
- **Parents:** partition of population eligible for reproduction.
- **Children:** generated through crossover of genes from parents.
- **Rest:** Rest of the population, mutated and moved to the next generation.

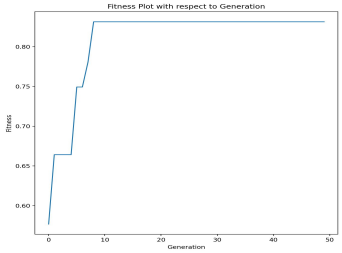
```
tm_size = 5
frac_elites = 0.2
frac_parents = 0.4
mutation_prob = 0.2
```

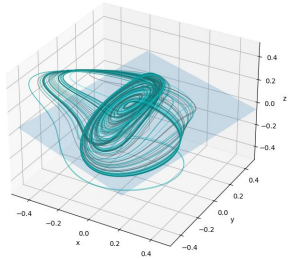


RANGE OF SOLUTIONS - SCALABLE DIMENSIONS/PLANES - NO DATA LABELING - FAST

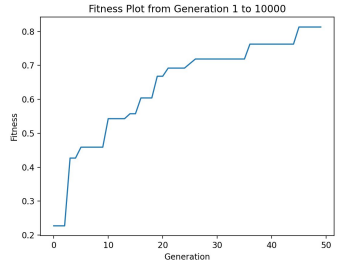
RESULTS

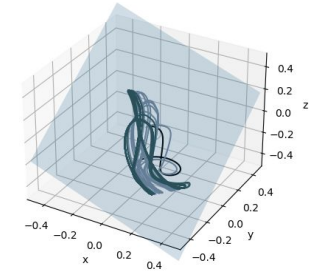
```
================================================================================================================
model_A: Halvorsen(name='Halvorsen', params={'a': 1.4, 'b': 4}, random_state=None)
model_B: Aizawa(name='Aizawa', params={'a': 0.95, 'b': 0.7, 'c': 0.6, 'd': 3.5, 'e': 0.25, 'f': 0.1}, random_state
plane_parameters: a = -0.17850277257206998 b = -0.21652278112048146 c = 0.9598201109791019 d = 0
other_parameters: t = 32.0, dt = 0.001, smooth = True, saved = True
initial_conditions: x0= -0.026489008129462678 y0= 0.016230841082386222 z0= -0.0013550960924706631
initial_conditions: x1= 0.014910440305610811 y1= -0.011323591105230221 z1= 0.007292449524125624
initial_conditions: x2= 0.049415450039478476 y2= 0.024032977365875258 z2= -0.019149705435753308
date_created: 2023-07-07 00:49:07.172789
uid: 20230707004907
lyapunov_exponent: 0.14300582691422245
================================================================================================================
```

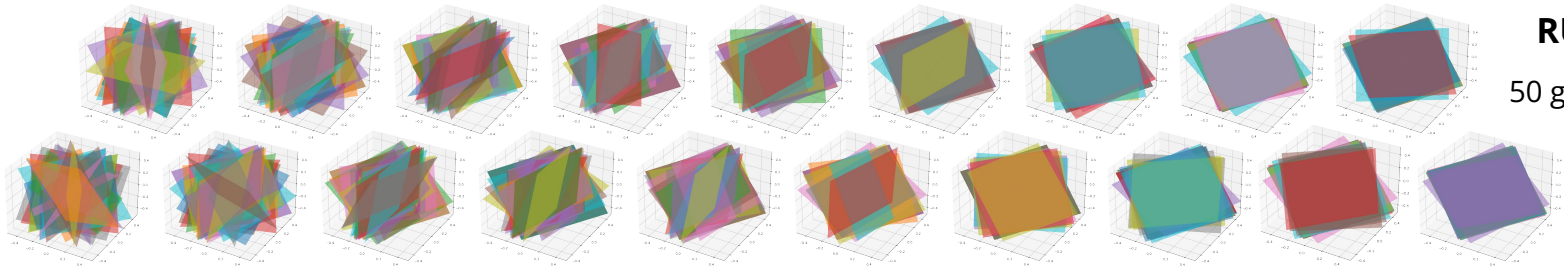




```
================================================================================================
model_A: Halvorsen(name='Halvorsen', params={'a': 1.4, 'b': 4}, random_state=None)
model_B: Rossler(name='Rossler', params={'a': 0.2, 'b': 0.2, 'c': 5.7}, random_state=None)
plane_parameters: a = 0.34671355487543265 b = -0.5963432981927279 c = 0.7239919761753301 d = 0
other_parameters: t = 8.0, dt = 0.01, smooth = True, saved = True
initial_conditions: x0= -0.007608984751638848 y0= -0.0023438234209063463 z0= 0.0414803942510769
initial_conditions: x1= -0.04921178401317458 y1= -0.004301358244412169 z1= 0.04055936892613636
initial_conditions: x2= 0.008512046293275066 y2= -0.04933419049993222 z2= 0.009256268640846589
date_created: 2023-07-06 07:34:43.448197
uid: 20230706073443
lyapunov_exponent: 0.6037045185378466
================================================================================================
```



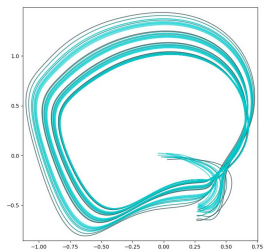
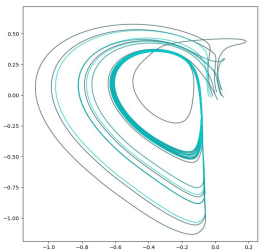
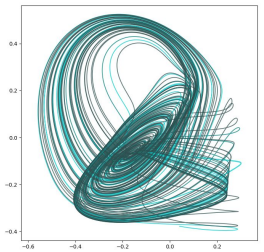
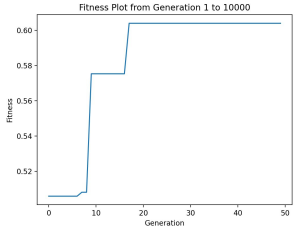


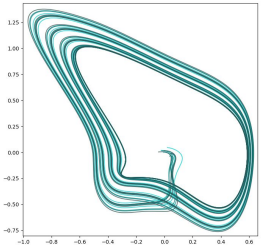
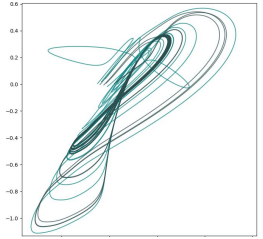
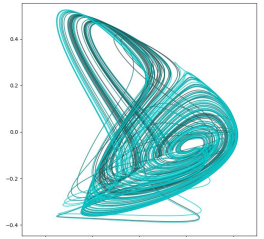
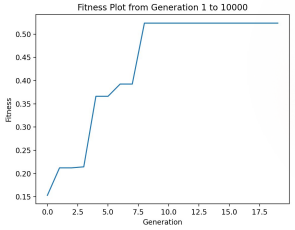


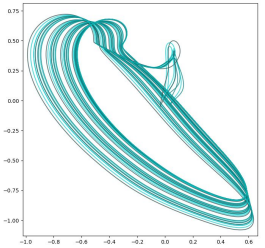
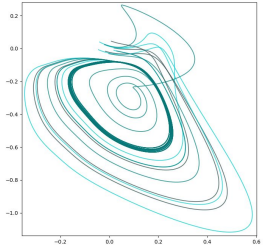
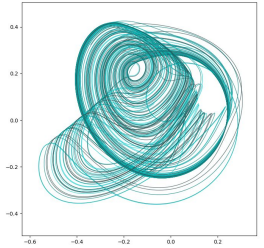
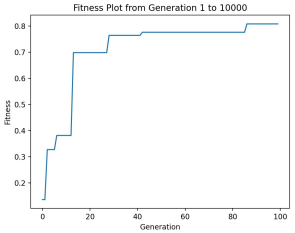
RUNTIME

50 generation
600 -1200
seconds

RESULTS

FUTURE WORKS

Experimenting with higher dimensions

sphere/oblique surface instead of plane

multiple planes and increased regions

References

Berenice Abbott, “A Bouncing Ball in Diminshing Arcs” (1958-1961), 54.6 × 45.7 cm, photograph mounted on Masonite with no glazing (Berenice Abbott Collection, MIT Museum. Gift of Ronald and Carol Kurtz © Getty Images/Berenice Abbott)

Sajad Jafari, J.C. Sprott, S. Mohammad Reza Hashemi Golpayegani, Elementary quadratic chaotic flows with no equilibria, Physics Letters A, Volume 377, Issue 9, 2013, Pages 699-702, ISSN 0375-9601, https://doi.org/10.1016/j.physleta.2013.01.009.

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Plane. from Wolfram MathWorld. https://mathworld.wolfram.com/Plane.html

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Thank you for your time.