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SEPTEMBER 18-22 2023 – ALGHERO, SARDINIA, ITALY

CYBER PHYSICAL SUMMER SCHOOL SYSTEMS 2023

A Hands-on Lab on Evolvable Self-* CPSs

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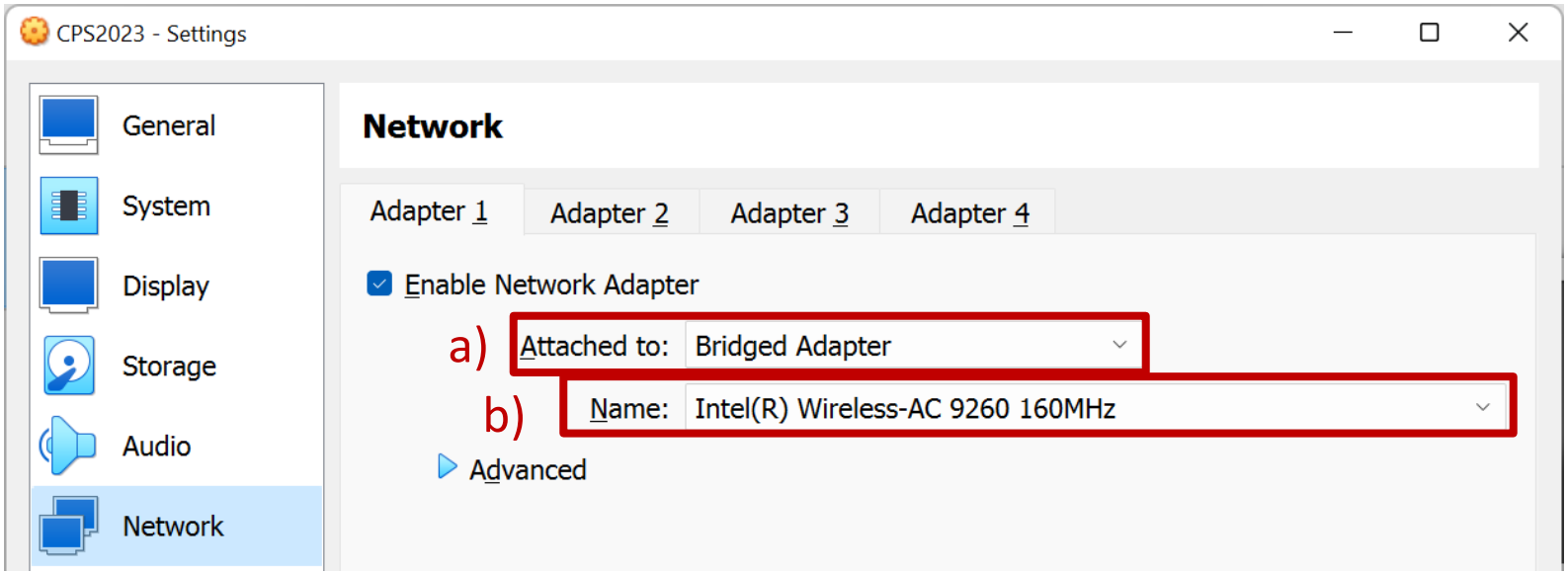
Before starting…

- … we need to set a couple of things up on the VM (initially off)

- 1. Make sure you are on network **DADU_Guest**
- 2. Change your VM **network configuration** to
  - a) use a **bridged adapter**
  - b) use your **wireless network adapter**



Before starting…

- … we need to set a couple of things up on the VM (initially off)

- 3. **Boot** the VM
- 4. Open a **terminal** and execute the following commands

```
pip3 install matplotlib

sudo apt-get install gcc-arm-linux-gnueabihf

git clone https://github.com/des-cei/artico3
cd artico3
git checkout cps23_tutorial
```

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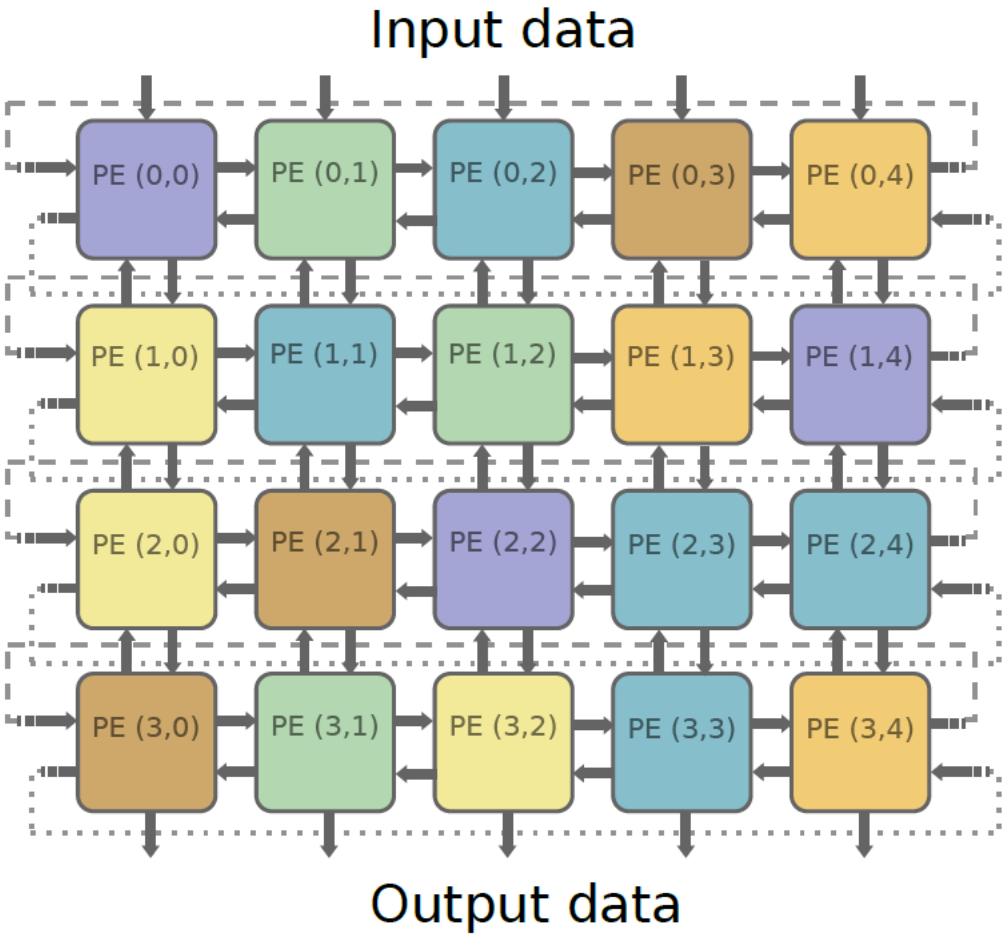
EXERCISE #1: BASIC EVOLUTIONARY ALGORITHM WITH BBNN MODELS

Block-based Neural Networks (BbNN)



S.-W. Moon, S.-G. Kong, “Block-based neural networks”, in IEEE Transactions on Neural Networks, vol. 12, no. 2, pp. 307–317, 2001,

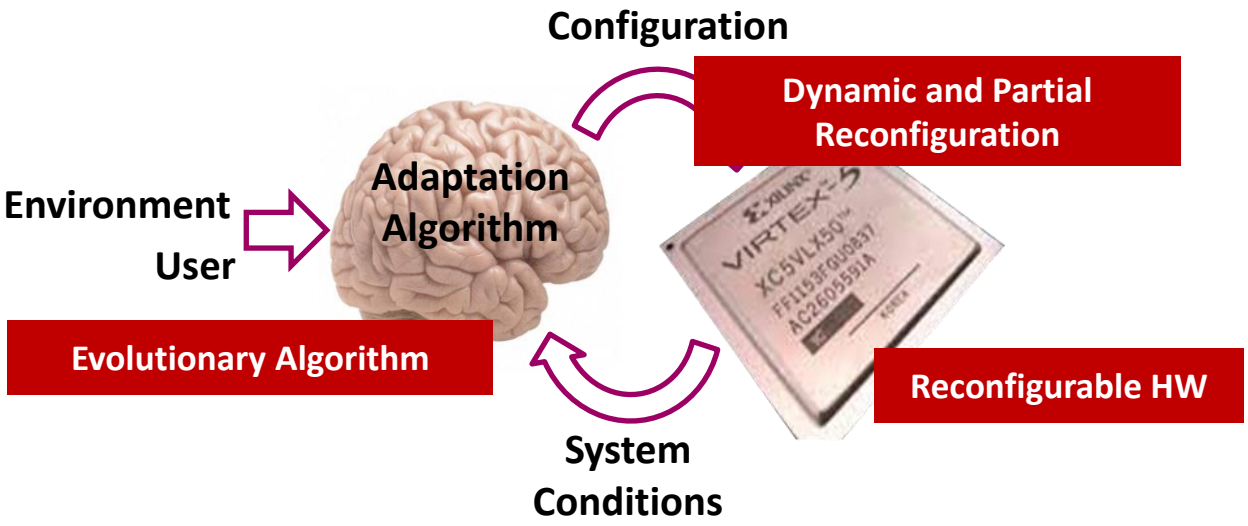
EXERCISE #2: ADAPTIVE IMAGE PROCESSING WITH EVOLVABLE HARDWARE

Overview

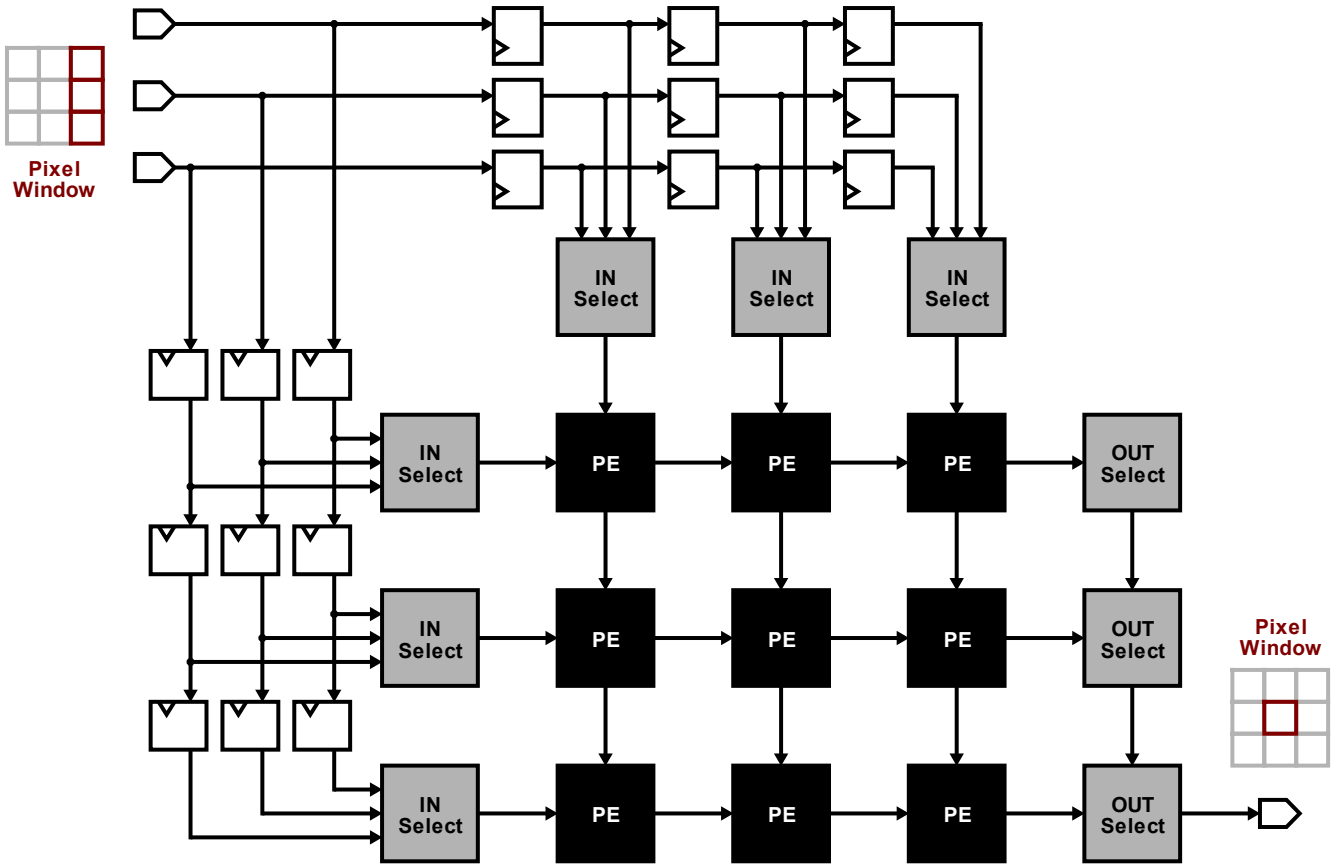
Goal #1: get a grasp on a real-world evolvable hardware system

Goal #2: evaluate an adaptation loop based on evolvable hardware

Goal #3: compare the adaptation loop with a random search approach



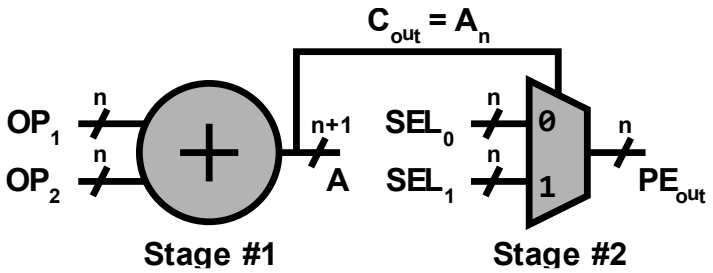
Reconfigurable Hardware Fabric



J. Mora, E. de la Torre, "Accelerating the evolution of a systolic array-based evolvable hardware system", in *Microprocessors and Microsystems*, vol. 56, pp. 144 – 156, 2018.

Reconfigurable Hardware Fabric

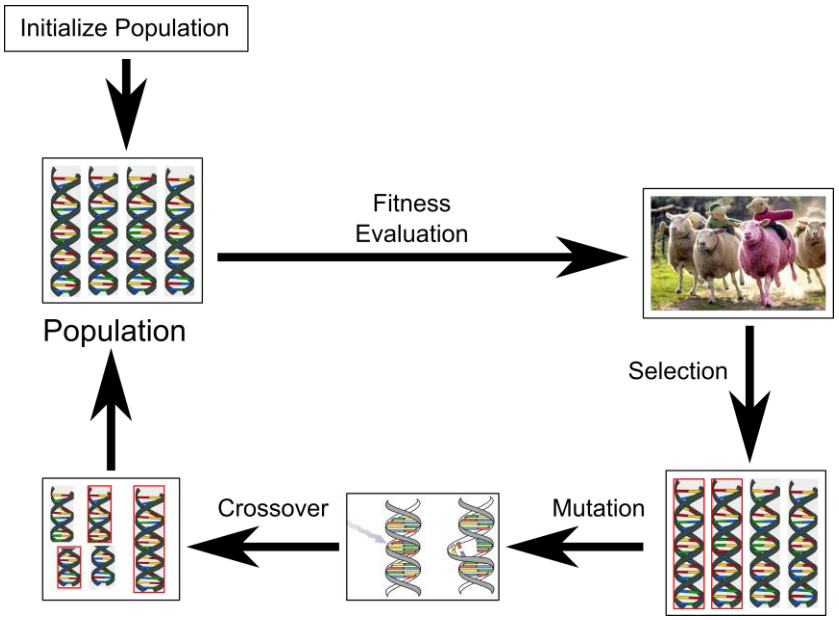
#	Function	Description
0	$N+W \bmod 2^n$	Addition (modulo 2^n)
1	$N+N \bmod 2^n$	Multiply by 2 (modulo 2^n)
2	$W+W \bmod 2^n$	
3	$\min(N+W, 2^n-1)$	Addition (saturated to 2^n-1)
4	$\min(N+N, 2^n-1)$	Multiply by 2 (saturated to 2^n-1)
5	$\min(W+W, 2^n-1)$	
6	$\lfloor \frac{N+W}{2} \rfloor$	Average (rounded down)
7	2^n-1	Constant value
8	$\lfloor \frac{N}{2} \rfloor$	Divide by 2 (rounded down)
9	$\lfloor \frac{W}{2} \rfloor$	
10	N	Identity (pass through)
11	W	
12	$\max(N, W)$	Maximum
13	$\min(N, W)$	Minimum
14	$\max(N-W, 0)$	Subtraction (saturated to 0)
15	$\max(W-N, 0)$	



J. Mora, E. de la Torre, "Accelerating the evolution of a systolic array-based evolvable hardware system", in *Microprocessors and Microsystems*, vol. 56, pp. 144 – 156, 2018.

Evolutionary Algorithm

Modified Genetic Algorithm (GA)



Alternatives

(1+λ) 1 population

λ·(1+1) λ populations, optional war

Chromosome Encoding: Integers

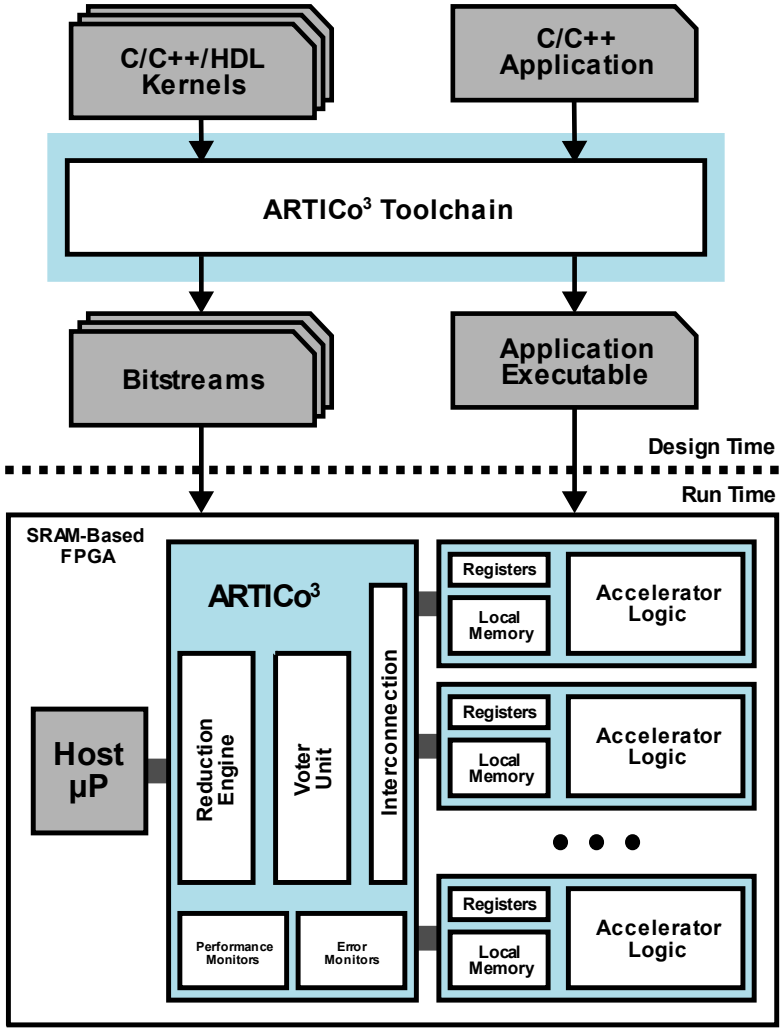
```
struct Chromosome {
    unsigned cfg[SA_WORDS];
};
```

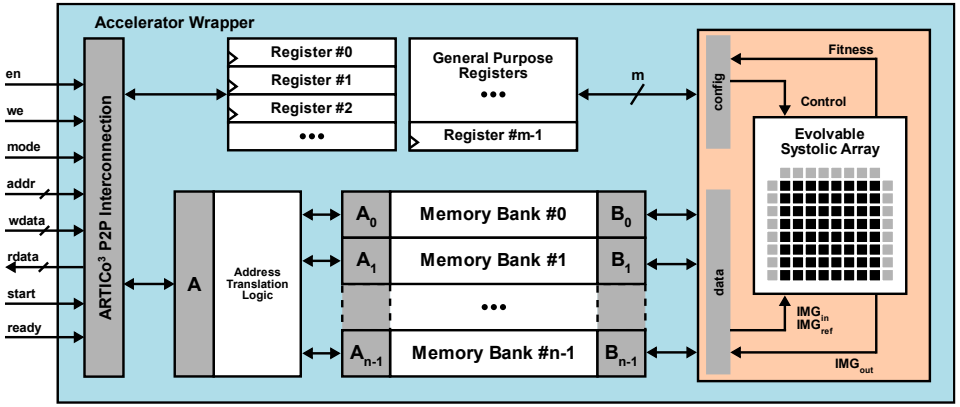
Fitness Function: SAE

$$SAE = \sum_{i=0}^{h-1} \sum_{j=0}^{w-1} \left| out_{i,j} - ref_{i,j} \right|$$

Genetic Operators: Mutation Only

Additional Infrastructure





A. Rodríguez, A. Otero, M. Platzner and E. de la Torre, "Exploiting Hardware-Based Data-Parallel and Multithreading Models for Smart Edge Computing in Reconfigurable FPGAs," in *IEEE Transactions on Computers*, vol. 71, no. 11, pp. 2903-2914, 1 Nov. 2022.

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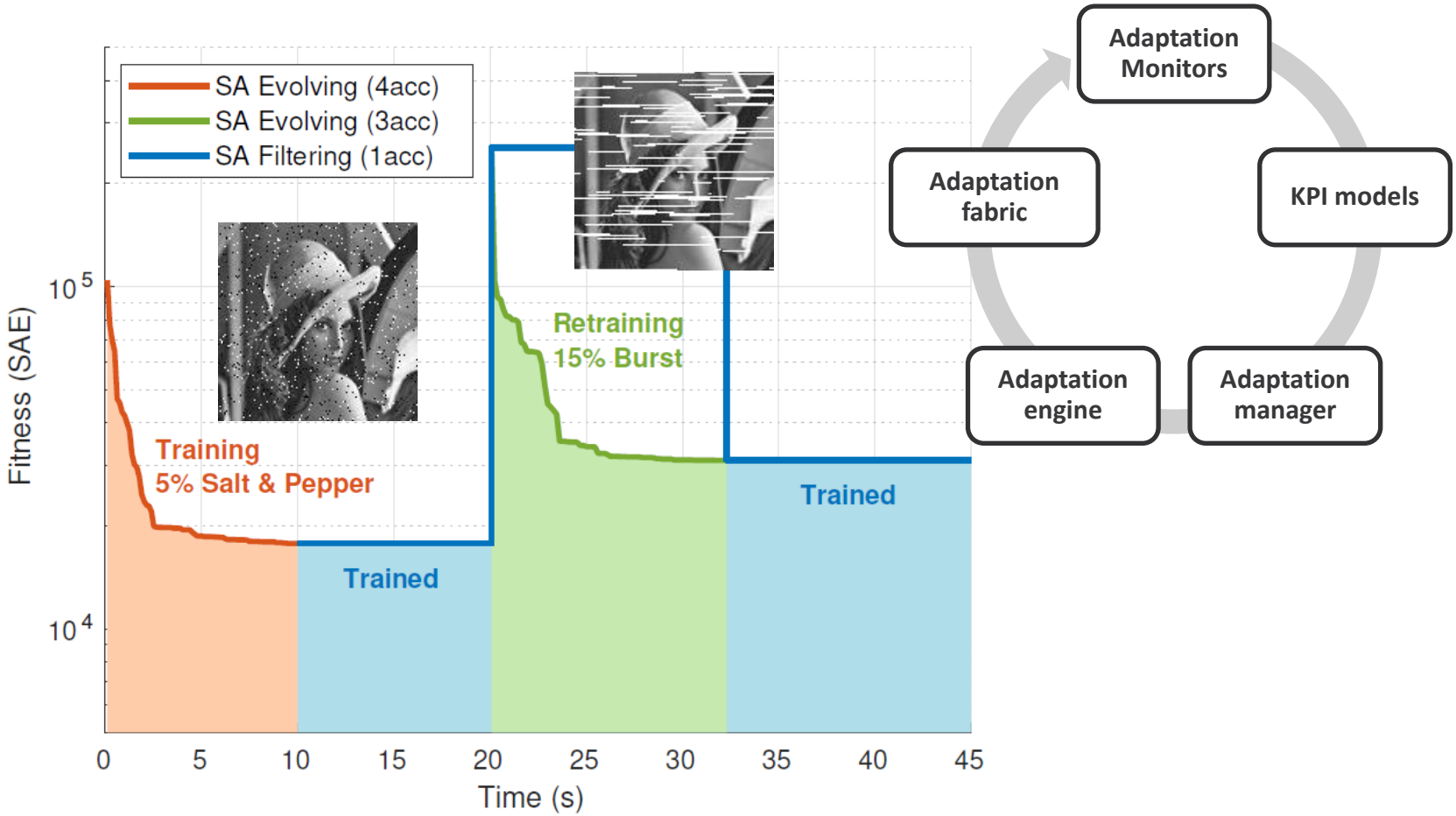

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Cheatsheet

- Log into Pynq board (host, pass: artico3)

```
ssh artico3@pynqXX.local
```

Replace XX with the number on your board!

- Open filesystem explorer on Pynq board (host)

```
sftp://pynqXX.local/home/artico3
```

- Set up environment and build SW application for ARTICo^3 (host)

```
cd artico3/demos/ehw
source ../../tools/settings.sh
a3dk

export_sw
build_sw -c arm-linux-gnueabihf- --busy-wait
clean_sw –r
```

- Run application (target)

```
cd /home/artico3/ehw
sudo ./ehw
```

Before running, make sure you copied executable from artico3/demos/ehw/build.sw

- Check results (host, but on remote folder over SFTP)

```
./plot.py
```

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GitHub

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