University of Cyprus

SAGA: A Surrogate Assisted Genetic Algorithm for Fast CPU Power Virus Generation

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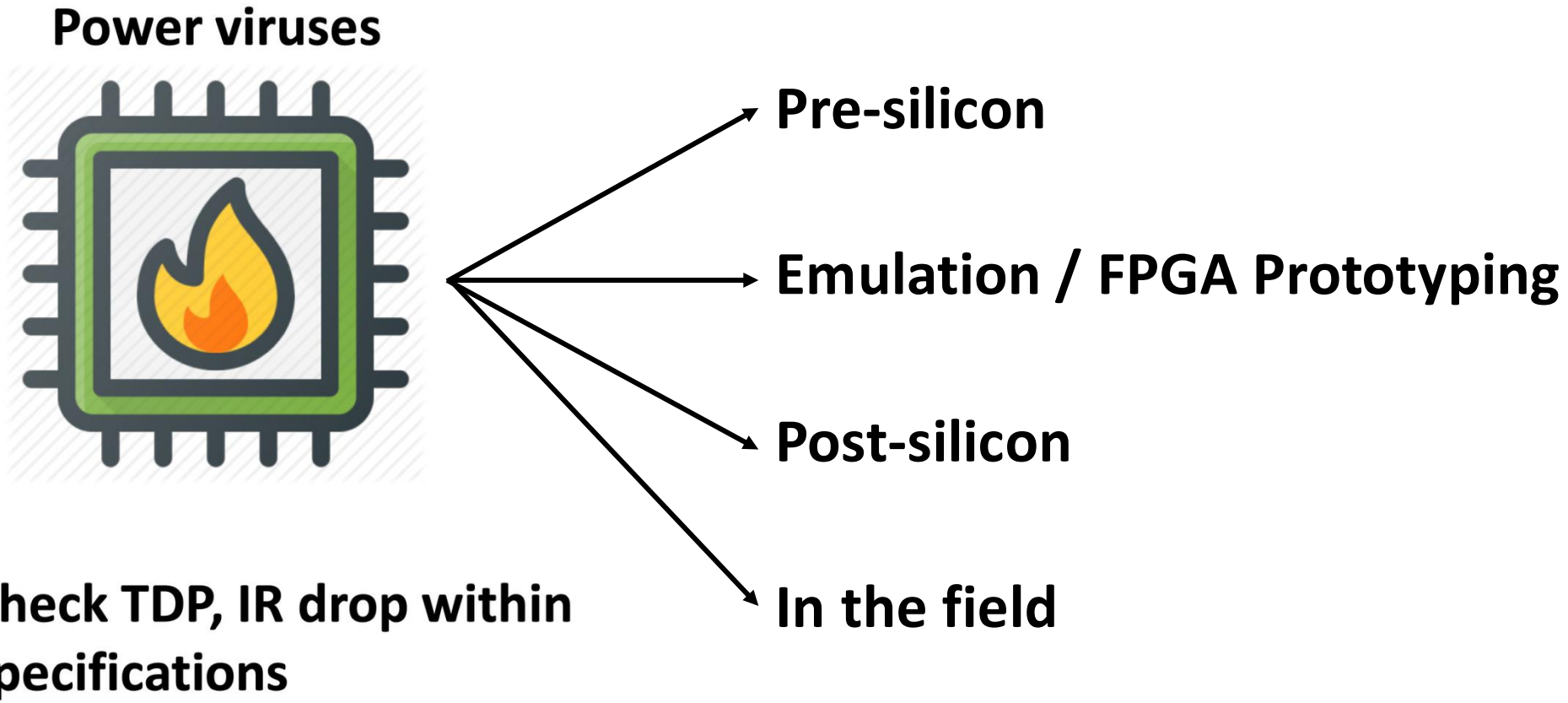
Motivation

- A stress-test that maximize power consumption of the CPU



Motivation

Power viruses

Check TDP, IR drop within specifications

Manual

Automatic

genetic algorithm

Approach	Effort	Time
Manual	❌ Tedious	❌ Slow
Automatic	✅ Minimal	❌ Slow (measurements)

Both manually crafting and automatic frameworks are very time-consuming!

Where does the GA spend the time?

genetic algorithm

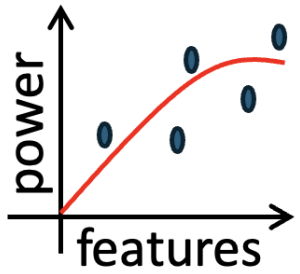
Power Virus

```
.start:

    vmulpd %ymm4,%ymm6,%ymm15
    mov 0(%rsp),%rdx
    mov 64(%rsp),%rsi
    mov 128(%rsp),%rdx
    vmaxpd %ymm13,%ymm1,%ymm7
    mov %rdx,%rsi
    vxorpd %ymm8,%ymm12,%ymm6
    add %rdx,100(%rsp)
    imul $644245065,%rax
    add $644245065,%rsi
    vmaxpd %ymm4,%ymm1,%ymm6
    imul %rsi,%rbx
    add $2147483550,%rax

jmp .start
```

Compilation → Execution → **power measurement**

Can we do something better?

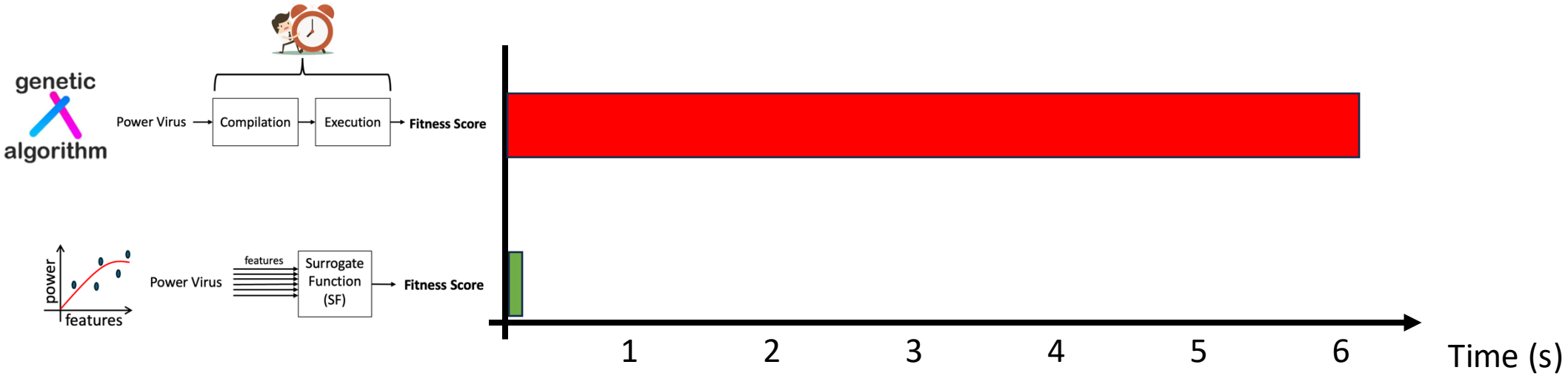
Surrogate Function (SF)



Power Virus

```
.start:

    vmulpd %ymm4,%ymm6,%ymm15
    mov 0(%rsp),%rdx
    mov 64(%rsp),%rsi
    mov 128(%rsp),%rdx
    vmaxpd %ymm13,%ymm1,%ymm7
    mov %rdx,%rsi
    vxorpd %ymm8,%ymm12,%ymm6
    add %rdx,100(%rsp)
    imul $644245065,%rax
    add $644245065,%rsi
    vmaxpd %ymm4,%ymm1,%ymm6
    imul %rsi,%rbx
    add $2147483550,%rax

jmp .start
```

features → Surrogate Function (SF) → **power measurement**



In this work

- Use of Surrogate Functions to accelerate power virus generation in GA-based frameworks (**SAGA**).
- Tested it on real-hardware across four different CPUs.
- Achieving up to 2x reduction in runtime compared to **GeST**, while achieving high quality results.

GeST [Z. Hadjilambrou, S. Das, P. N. Whatmough, D. Bull and Y. Sazeides, "GeST: An Automatic Framework For Generating CPU Stress-Tests," **2019 IEEE International Symposium on Performance Analysis of Systems and Software (ISPASS)**]

Rest of the Presentation

- Genetic Algorithm Flow
- Use of Surrogate Functions
- SAGA
- Experimental Evaluation
- Conclusion

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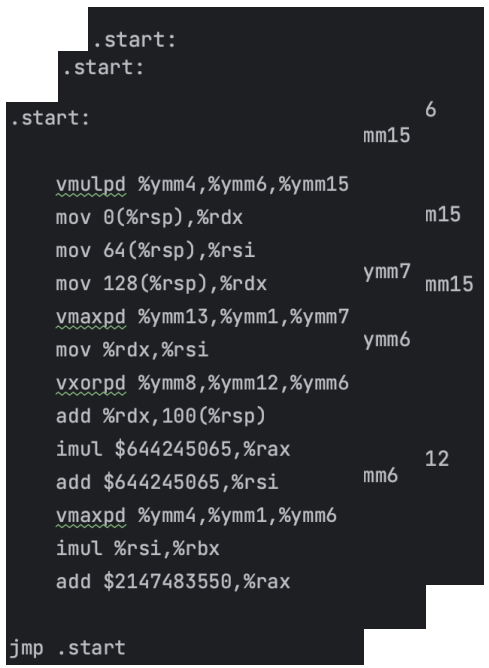
Genetic Algorithm Flow

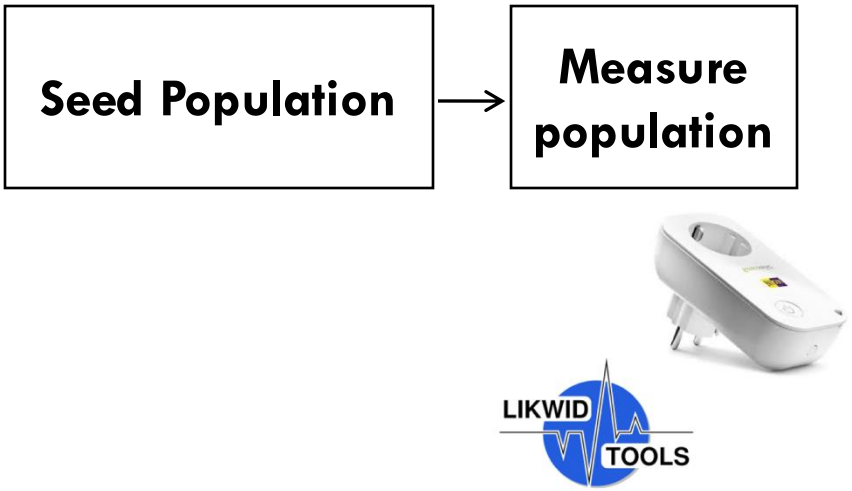
Seed Population



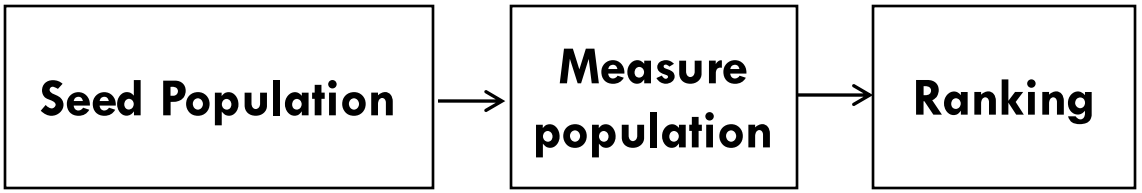
A collection of instruction sequences (**individuals – stress tests**)

Population size = 50 individuals

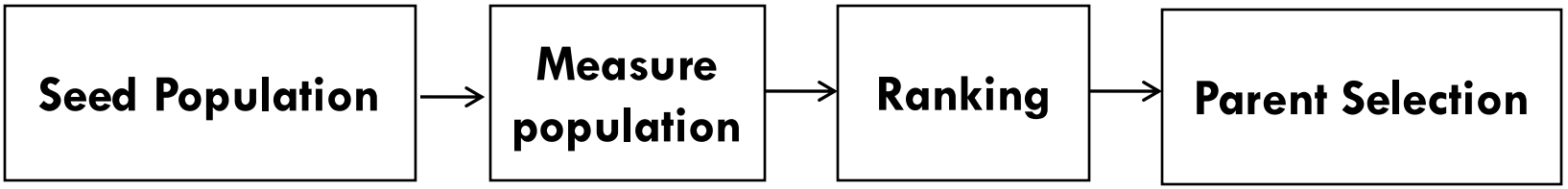
Genetic Algorithm Flow



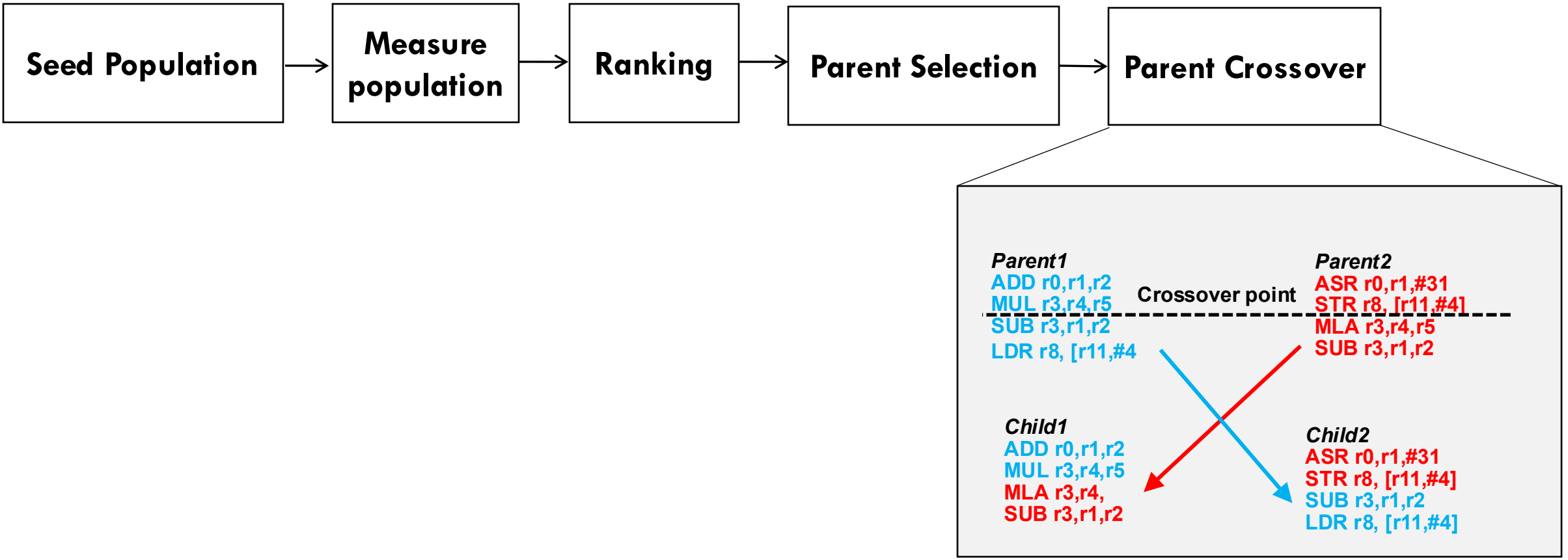
Genetic Algorithm Flow



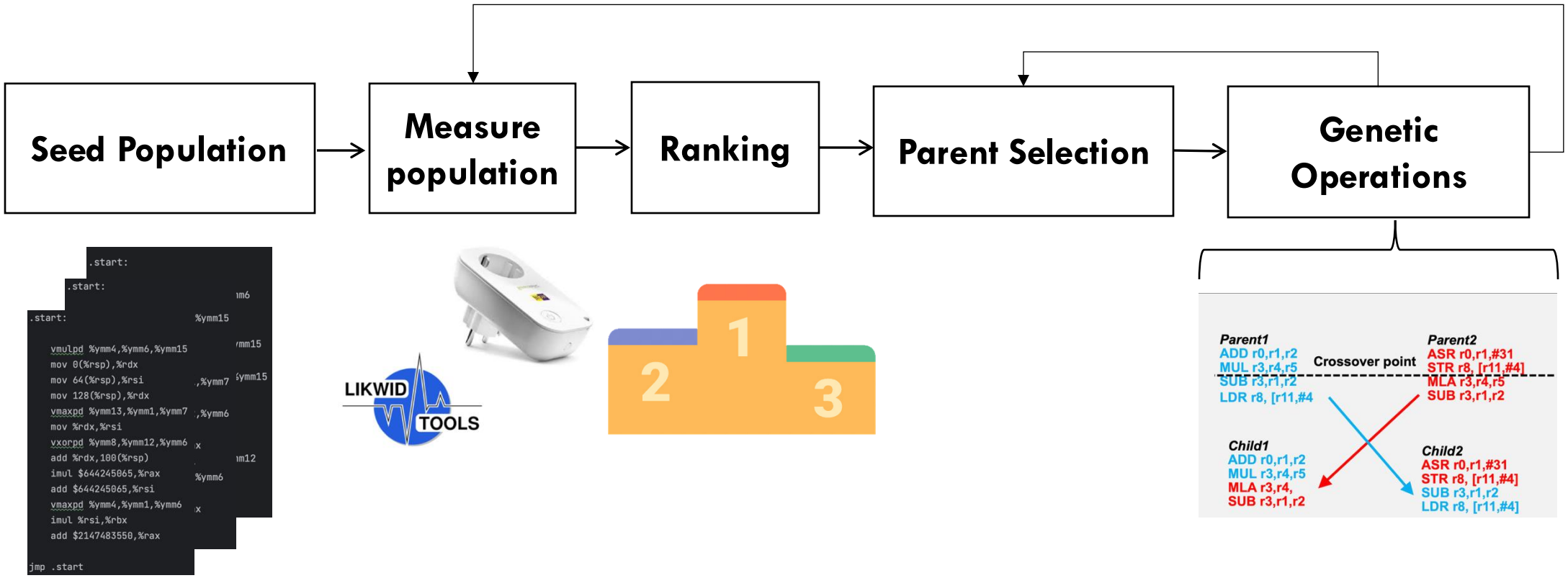
Genetic Algorithm Flow



Genetic Algorithm Flow



Genetic Algorithm Flow



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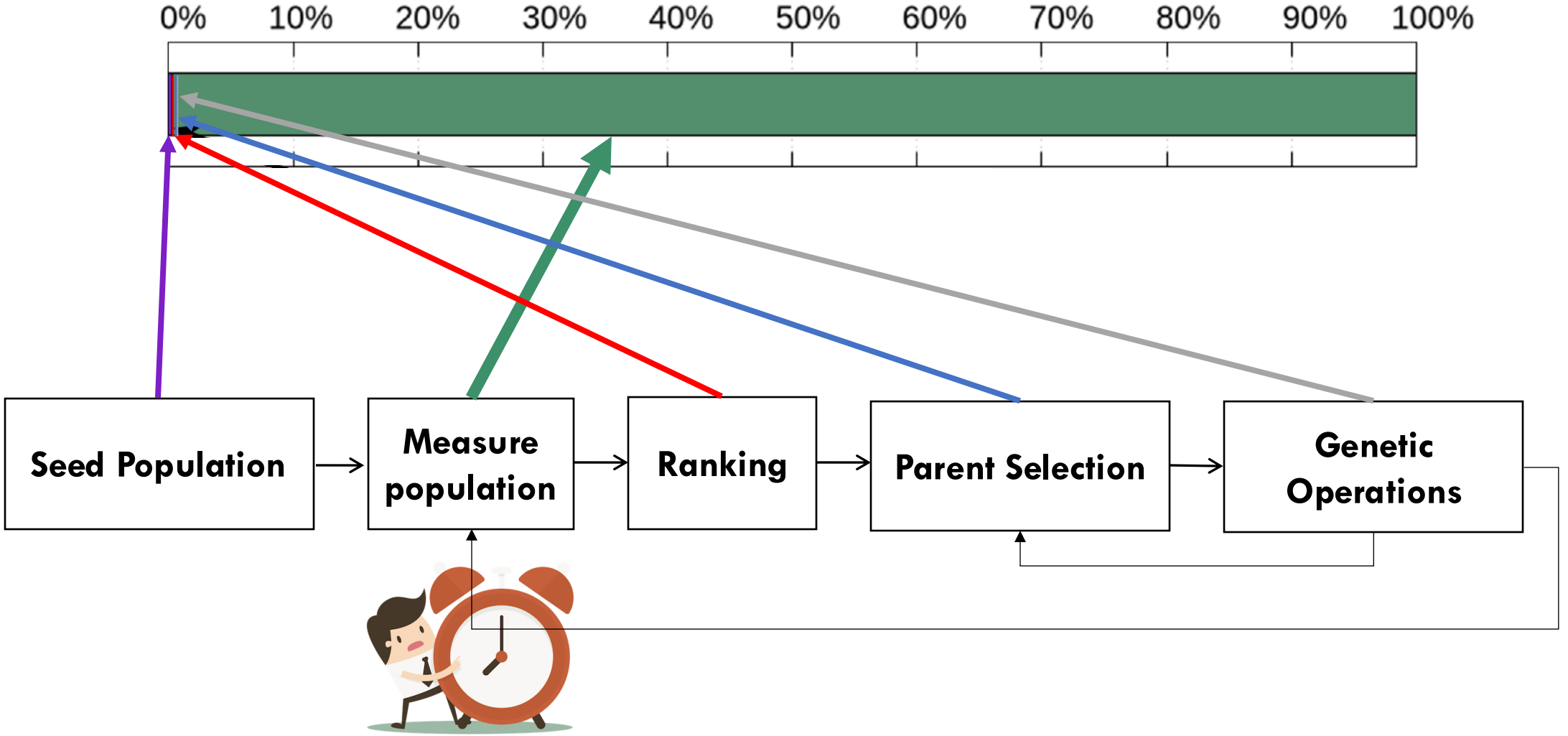
Genetic Algorithm's Generation Time Distribution



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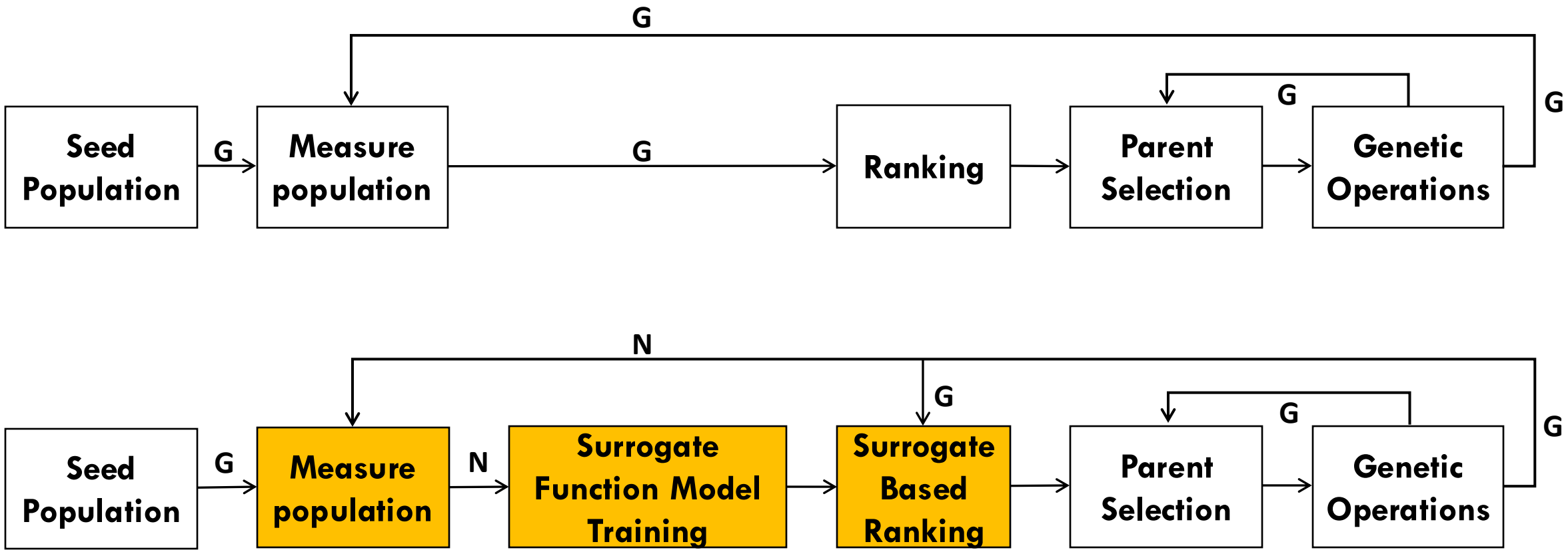
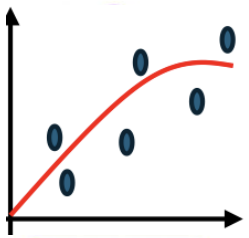
The Use of Surrogate Functions (SF)



Key parameters of a Surrogate Function

Features

What input features are used to describe a virus



Prediction Model

ML model used to approximate fitness

Training Set

Data used to train the prediction model

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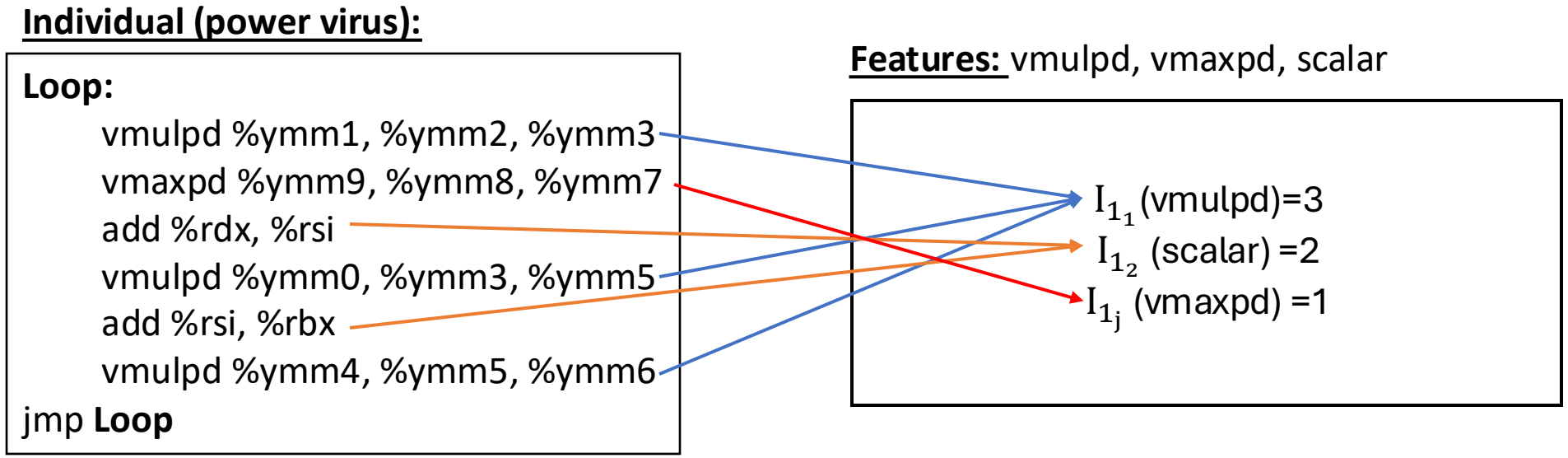
SAGA's Features

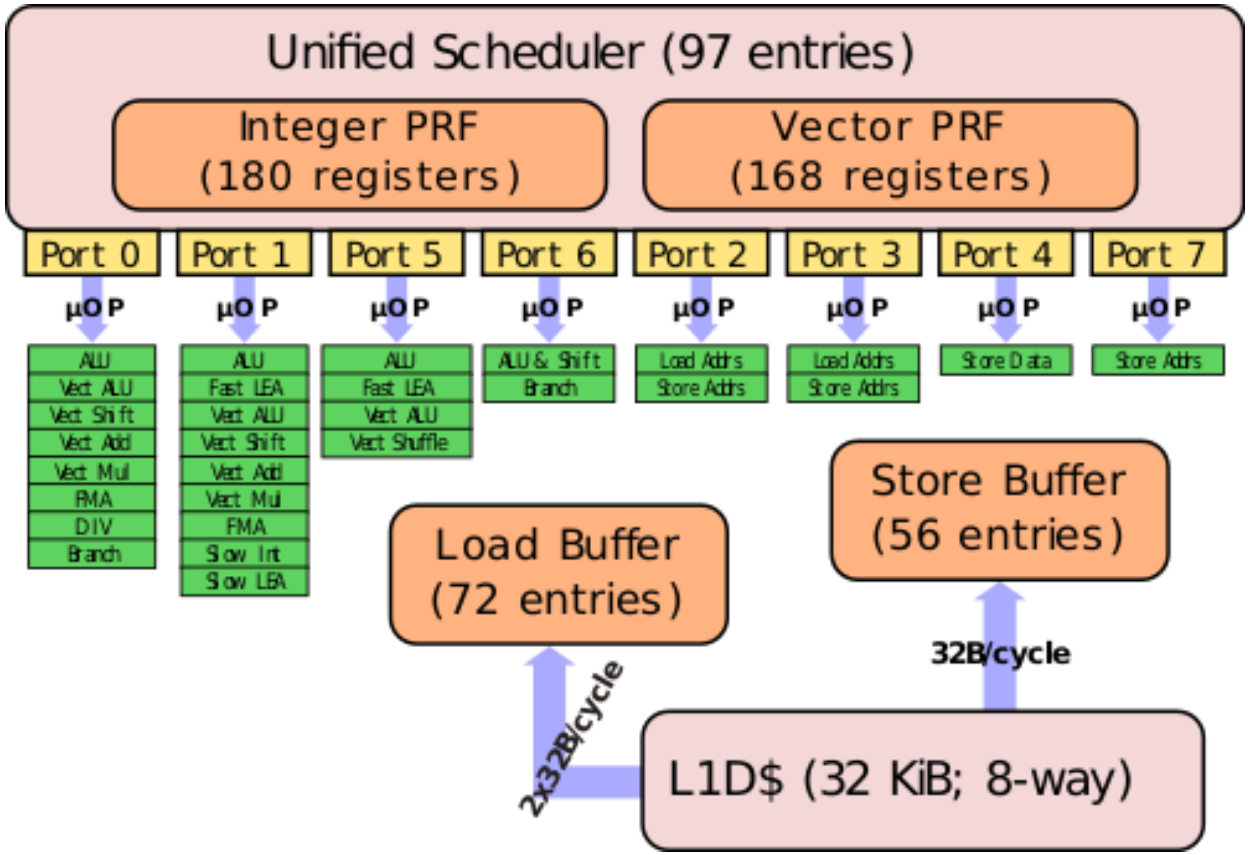
- **Input features:** Number of Instructions for each instruction type.



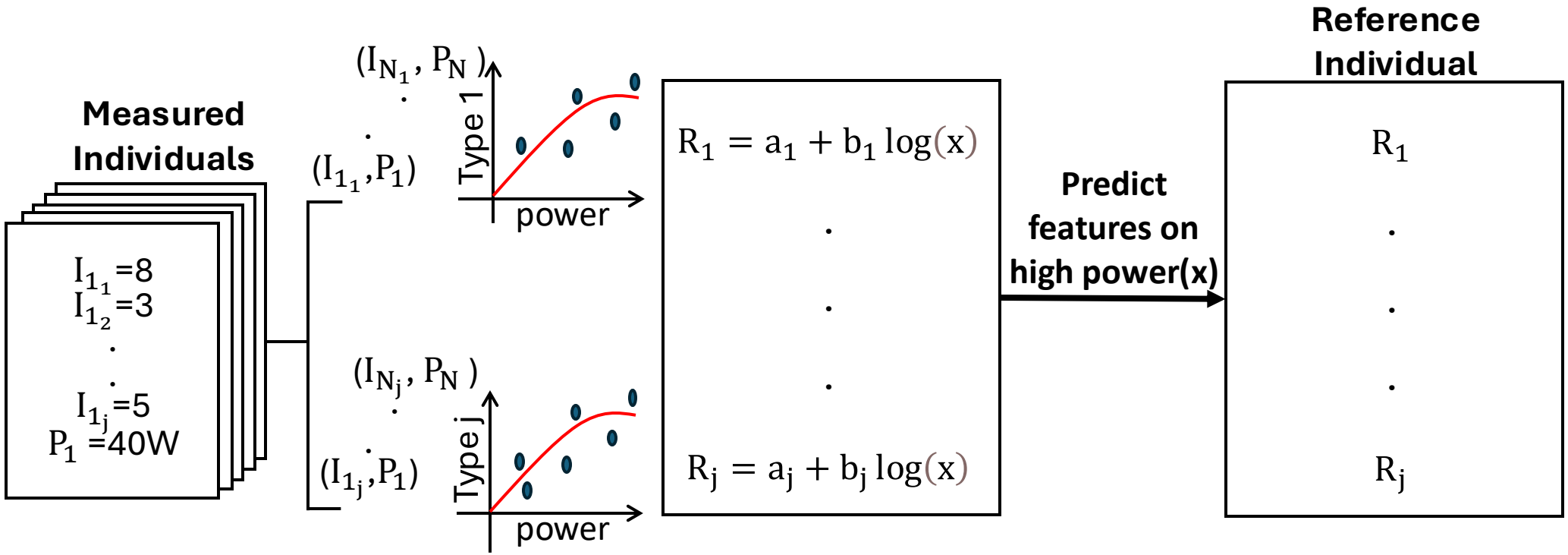
Intuition behind SAGA's Features

- **Input features:** Number of Instructions for each instruction type.

- Different Instructions stress different execution ports.
- Correlate instruction mixes with power draw.
- GA discovers instruction-level parallelism to account for dependencies.



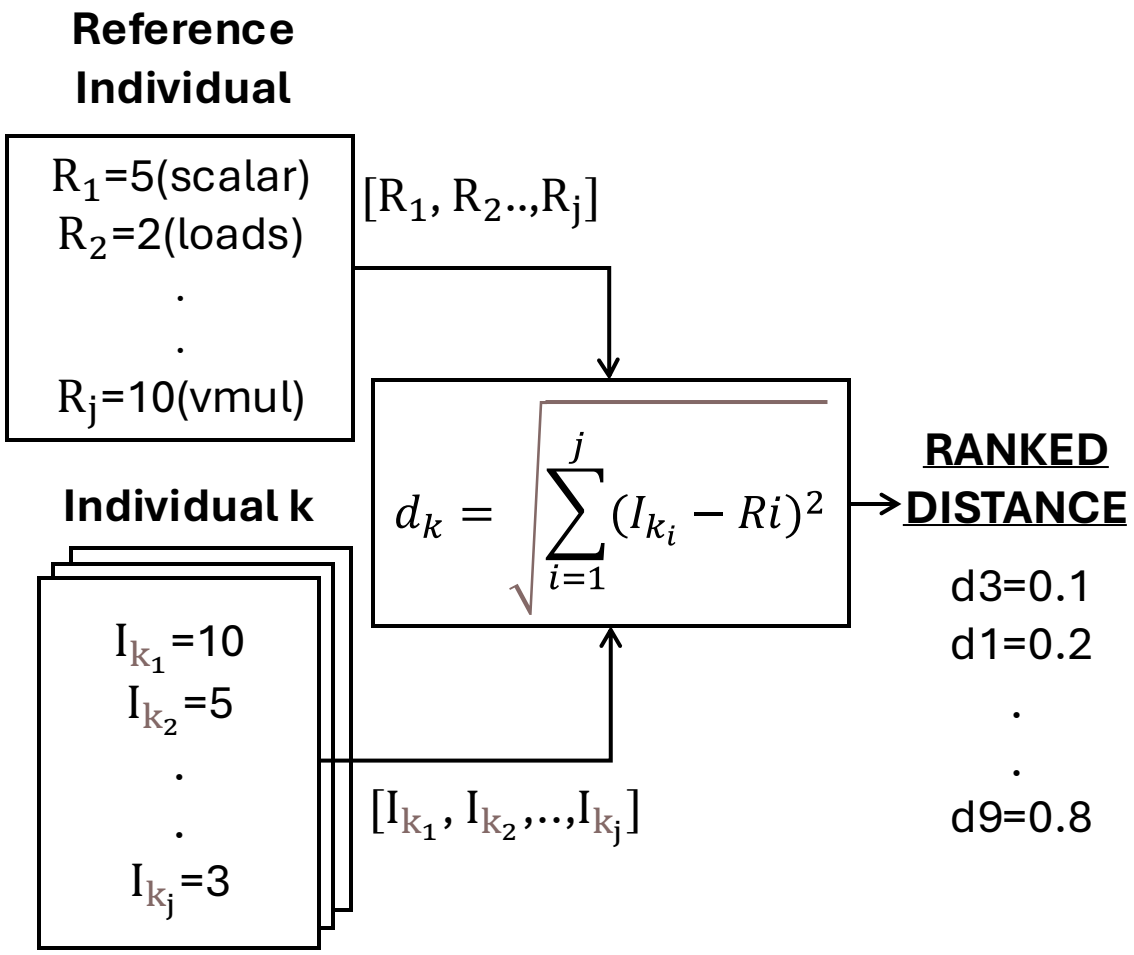
SAGA's Prediction Model – training / training set



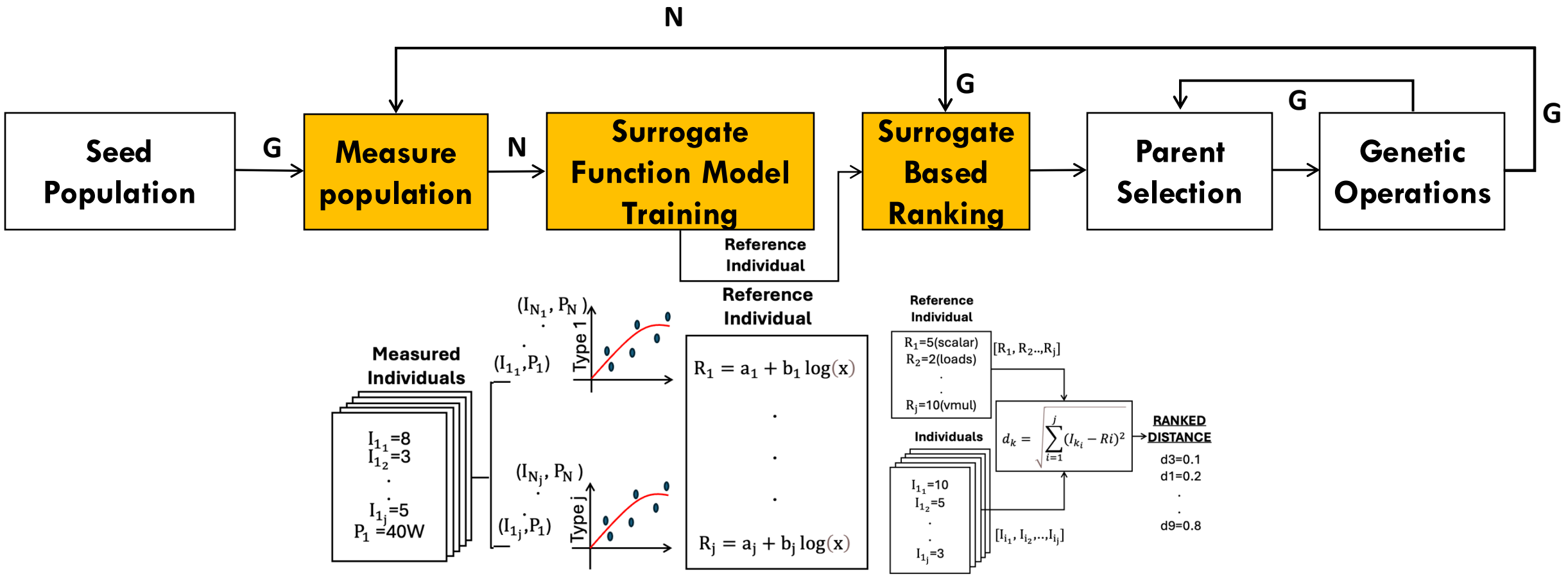
Reference Individual

- **Acts like a compass!**
- It isn’t a real program, but provides the characteristics of a virus with high power consumption!

SAGA's Ranking



SAGA's high-level flow



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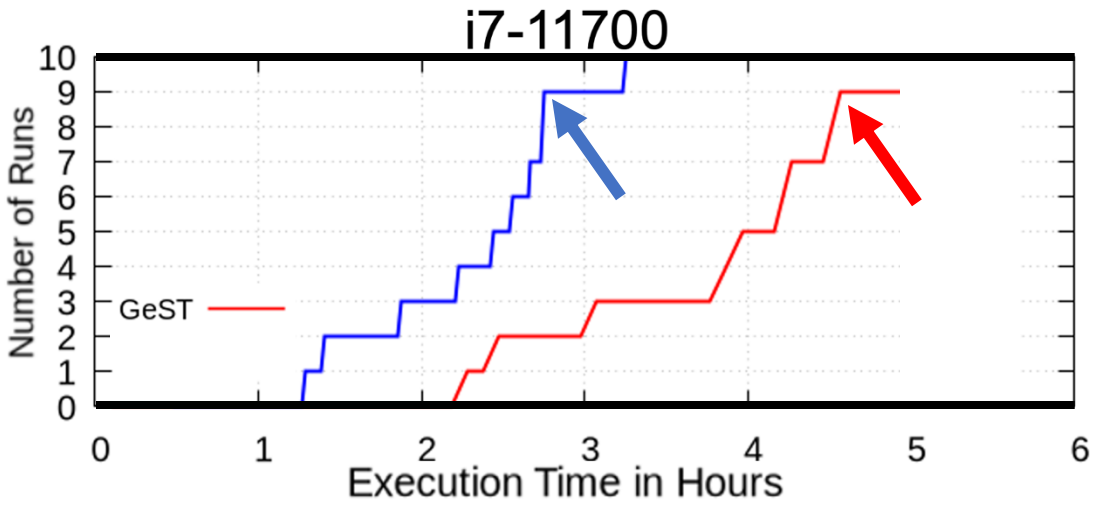
Experimental Methodology

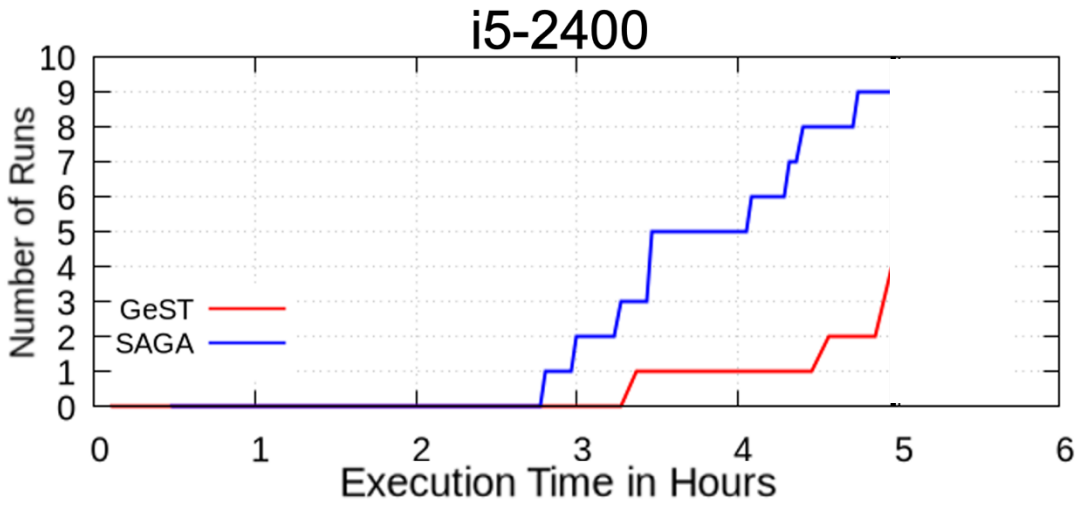
Platforms:

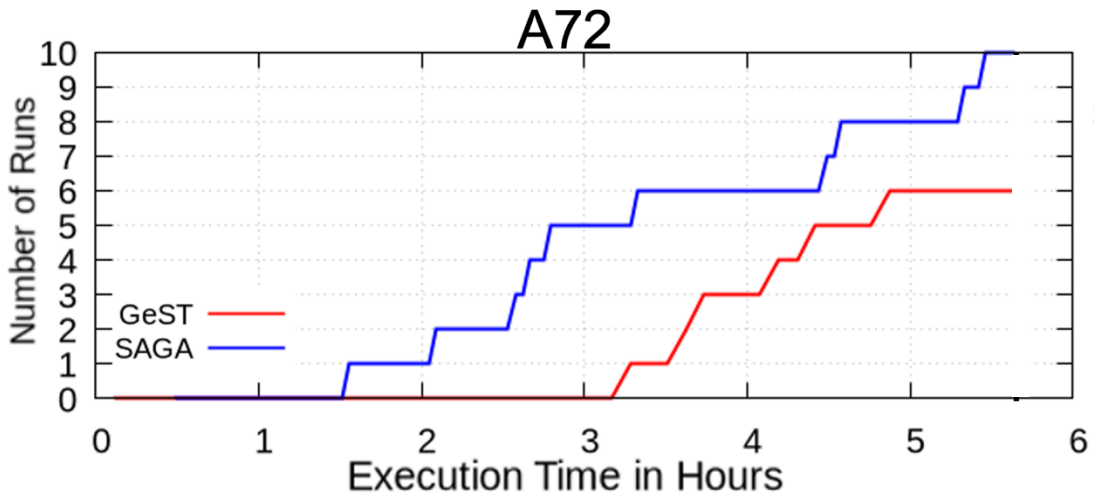
CPU	ISA	Measurement Instrument
Intel(R) Core(TM) i7-11700	x86	Likwid-powermeter
Intel(R) Core(TM) i5-2400	x86	Likwid-powermeter
Arm-Cortex-A72	Armv8-A	Arm Energy Probe
Arm-Cortex-A53	Armv8-A	Arm Energy Probe

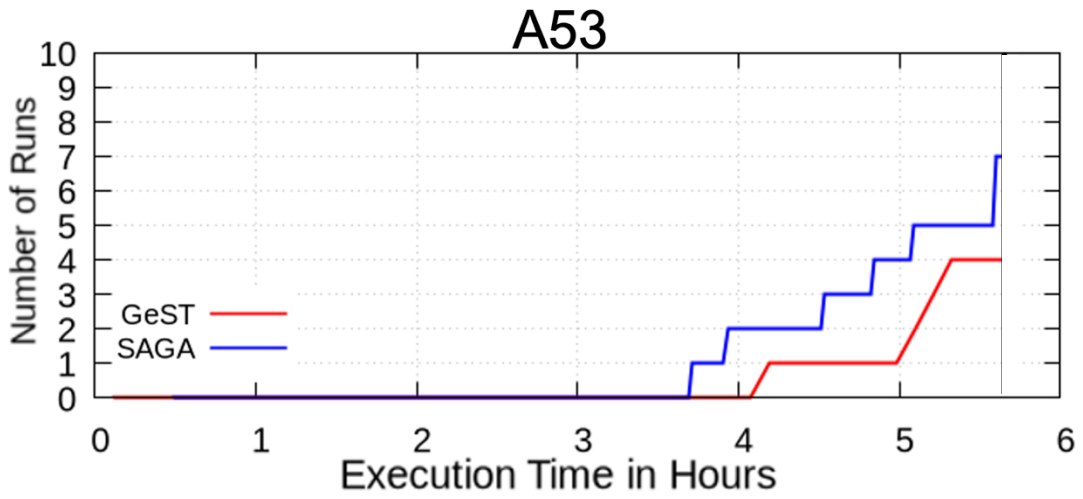
- Integrate SAGA into GeST.
- Run each method 10 times on each platform.
- Successful threshold: 95^{th} percentile.

SAGA vs GeST

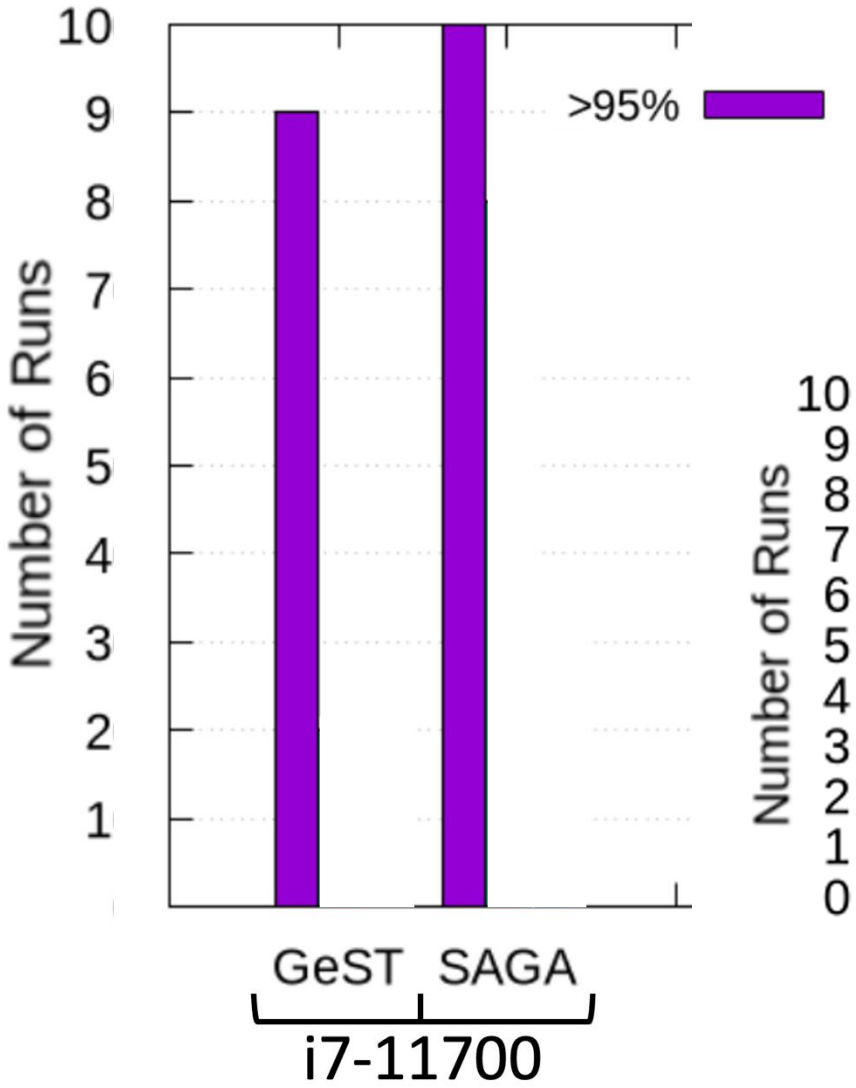

i7-11700
Number of Runs
Execution Time in Hours
GeST

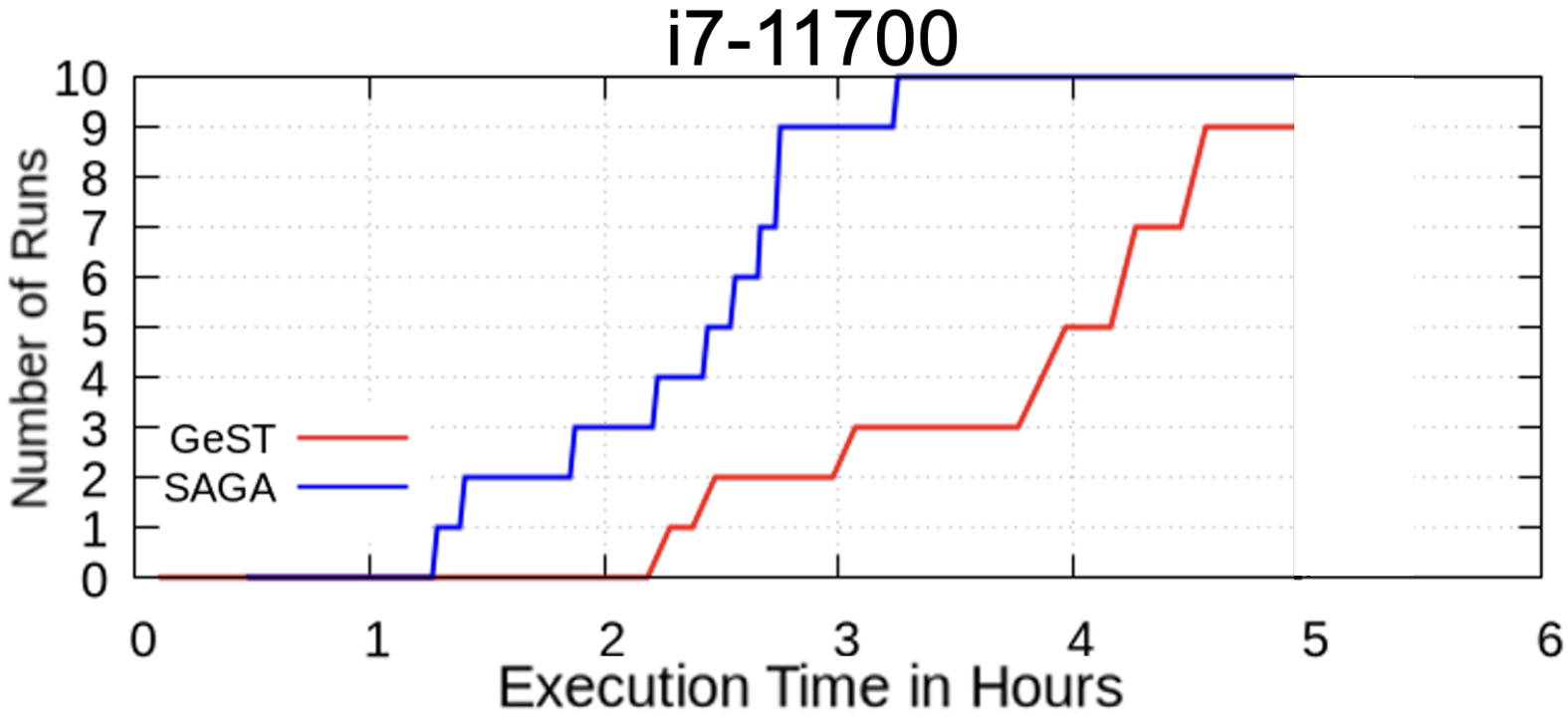

i5-2400
Number of Runs
Execution Time in Hours
GeST
SAGA


A72
Number of Runs
Execution Time in Hours
GeST
SAGA


A53
Number of Runs
Execution Time in Hours
GeST
SAGA

SAGA vs GeST





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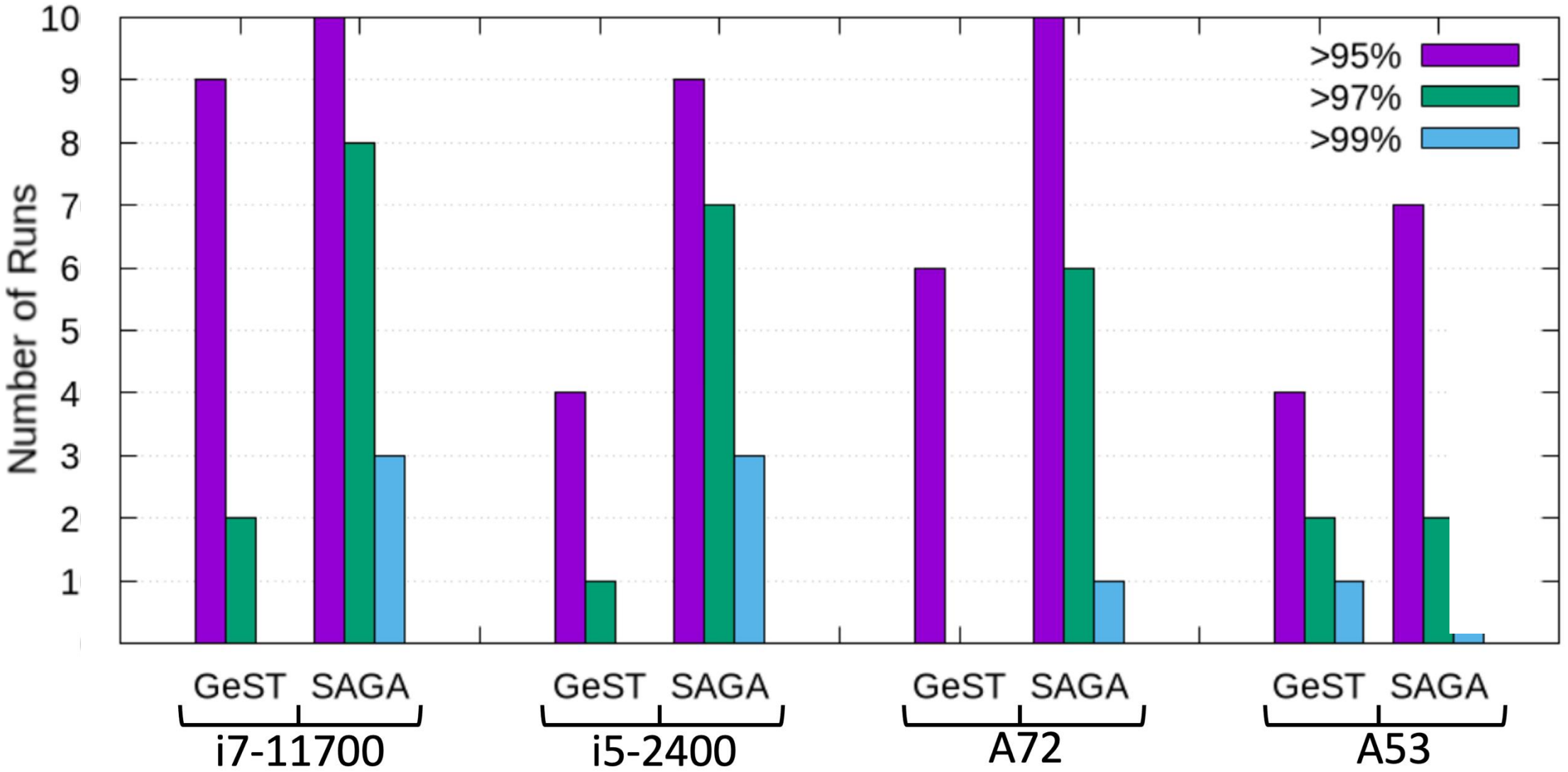
SAGA vs GeST


Number of Runs
10
9
8
7
6
5
4
3
2
1
>95%
>97%
>99%
GeST
SAGA
i7-11700
GeST
SAGA
i5-2400
GeST
SAGA
A72
GeST
SAGA
A53

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Conclusions

- Introduction of SF acceleration for virus generation in GA-based frameworks.
- Tested it on real-hardware across four different CPUs.
- Achieving up to 2x reduction in runtime, while achieving higher quality results.
- SAGA can be used for other types of slow optimization problems, by defining the right surrogate model.
- SAGA is publicly available **and it's free!**

https://www2.cs.ucy.ac.cy/carch/xi/gest_tool.php

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