



<http://cs.adelaide.edu.au/~markus/>



# An Academic Optimisation Problem in Logistics and Two Real-World Optimisation Problems Related to Energy

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University: T



# OPTIMISATION AND LOGISTICS

## Foundations of Heuristics

### Renewable Energy



Coordinator:  
Dr Markus Wagner

### Algorithmic Game Theory



Coordinator:  
Dr Mingyu Guo



Coordinator:  
Prof Frank Neumann

### Staff Profile:

6 faculty members  
2 postdocs  
8 PhD students

### Search-based Software Engineering



Coordinator:  
Dr Bradley Alexander

### Supply Chain Management



Coordinator:  
Dr Sergey Polyakovskiy

# OPTIMISATION AND LOGISTICS

## Supply Chain Management (Australian Research Council funded)

- Large scale industrial optimisation problems with many interacting components.

## Dynamic Constraints (ARC funded)

- Algorithms for problems with dynamically changing constraints.

## Dynamic Adaptive Software Configurations (ARC funded)\*

- Self-adapt system configurations to changing conditions.

Lots of other knowledge, either in-house or via international collaborations, e.g. more theory, system modelling, speed-up of simulations (algorithmically or using machine learning)...

# SOME OF THE ACTIVITIES OF OPTIMISATION AND LOGISTICS 2016-2018

- **ACM Genetic and Evolutionary Computation Conference 2016**  
(General Chair: Frank Neumann)
- **NII Shonan Meeting on “Computational Intelligence for Software Engineering**, Shonan Village Centre, Japan.  
Organizers: Hong Mei (Peking), Frank Neumann (UoA),  
Xin Yao (Birmingham)
- **Dagstuhl Seminar on “Automatic Algorithm Selection and Configuration”**, Schloss Dagstuhl, Germany  
Organizers: Heike Trautmann (Muenster), Holger Hoos (Vancouver), Frank Neumann (UoA).
- **NII Shonan Meeting on “Data-Driven Search-Based Software Engineering”**, Shonan Village Centre, Japan.  
Organizers: Markus Wagner (UoA), Leandro Minku (Leicester), Ahmed E. Hassan (Queens U),  
John Clark (York)
- **Australasian Conference on Artificial Life and Computational Intelligence 2018**  
(General Chair: Markus Wagner)
- **International Workshop on Benchmarking of Computational Intelligence Algorithms, BOCIA**,  
<http://iao.hfuu.edu.cn/bocia18>  
(Co-Chair: Markus Wagner)

# MARKUS WAGNER

2003-2009



2006-2007



2010-2013



2013



Senior Lecturer

Summary:

80+ papers/co-authors/reviews/events/...  
1 best paper/poster/presentation/keynote/medal/...  
**2nd time in Hefei ☺**

IEEE CIS:

Chair University Curricula 2016/2017  
Chair Educational Material Subcommittee 2014/2015  
Founding Chair of Task Force "CI in the Energy Domain"

TODAY: change in plans!

The "logistics problem" will come later.  
Let us look at APPLICATIONS first.



# Programming is Hard!

```
$.fn.scrollTop = function( to, easing, duration ) {
  var scrollTarget = to || 0;
  return this.each(function( i, window ) {
    $.fn.scrollTo( this, scrollTarget, {
      duration: duration,
      easing: easing,
      offset: 0
    } );
  });
};

$.fn.scrollTo = function( target, options ) {
  options = options || {};
  var $target = $(target);
  if (!$target.length) {
    return;
  }
  var $window = $(this);
  var scrollLeft = options.scrollLeft || 0;
  var scrollRight = options.scrollRight || 0;
  var scrollTop = options.scrollTop || 0;
  var scrollBottom = options.scrollBottom || 0;
  var offset = options.offset || 0;
  var targetLeft = $target.offset().left;
  var targetRight = $target.offset().left + $target.width();
  var targetTop = $target.offset().top;
  var targetBottom = $target.offset().top + $target.height();
  var left = scrollLeft;
  var right = scrollRight;
  var top = scrollTop;
  var bottom = scrollBottom;
  if (options.scrollTo === 'left') {
    left = targetLeft;
  } else if (options.scrollTo === 'right') {
    right = targetRight;
  }
  if (options.scrollTo === 'top') {
    top = targetTop;
  } else if (options.scrollTo === 'bottom') {
    bottom = targetBottom;
  }
  if (options.offset !== 0) {
    left += offset;
    right += offset;
    top += offset;
    bottom += offset;
  }
  if (left === scrollLeft || right === scrollRight || top === scrollTop || bottom === scrollBottom) {
    return;
  }
  var $element = $window;
  var elementLeft = $element.offset().left;
  var elementRight = $element.offset().left + $element.width();
  var elementTop = $element.offset().top;
  var elementBottom = $element.offset().top + $element.height();
  var animateLeft = left < elementLeft;
  var animateRight = right > elementRight;
  var animateTop = top < elementTop;
  var animateBottom = bottom > elementBottom;
  if (!animateLeft && !animateRight && !animateTop && !animateBottom) {
    return;
  }
  var animate = {
    left: animateLeft ? left : null,
    right: animateRight ? right : null,
    top: animateTop ? top : null,
    bottom: animateBottom ? bottom : null
  };
  $element.animate(animate, options.duration, options.easing);
};
```



<http://phdopen.mimuw.edu.pl/zima15/petke-slides/gi.pdf>

## Functional Requirements



functionality of the Program

## Non-Functional Requirements



Execution Time



Memory



Bandwidth



Battery



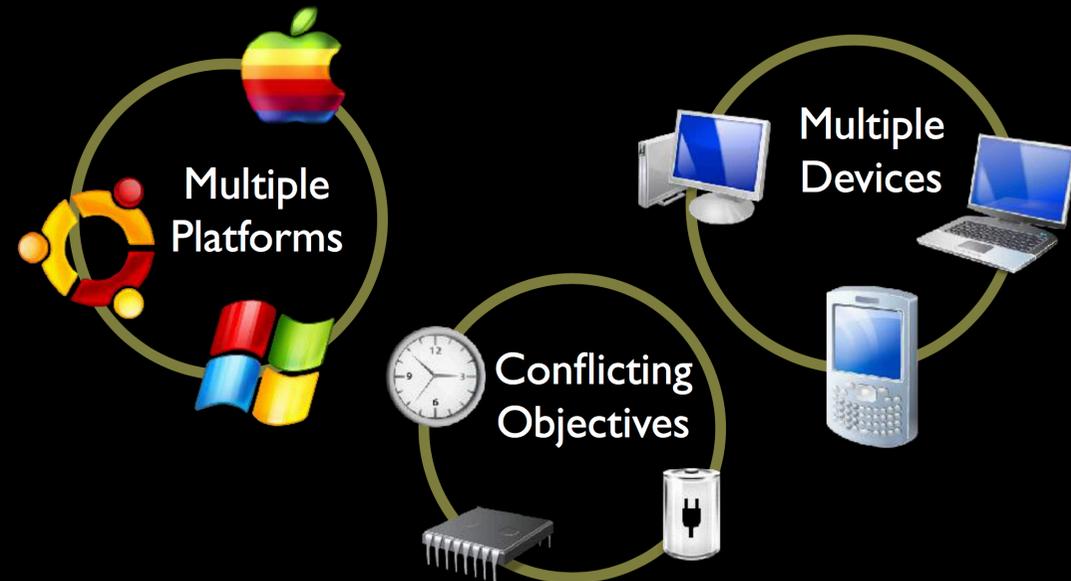
Size

CREST

Genetic Improvement

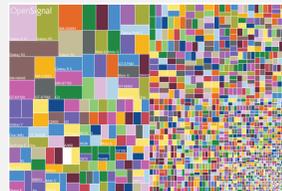
Justyna

# Multiplicity



Note: over 24,000 different Android phones in 2015

<https://qz.com/472767/there-are-now-more-than-24000-different-android-devices/>



CREST

Genetic Improvement

Justyna Petke



DEEP PARAMETER OPTIMISATION ON ANDROID  
SMARTPHONES FOR ENERGY MINIMISATION  
- A TALE OF WOE AND A PROOF-OF-CONCEPT -

Mahmoud A. Bokhari, Bobby R. Bruce (UCL),  
Brad Alexander and Markus Wagner

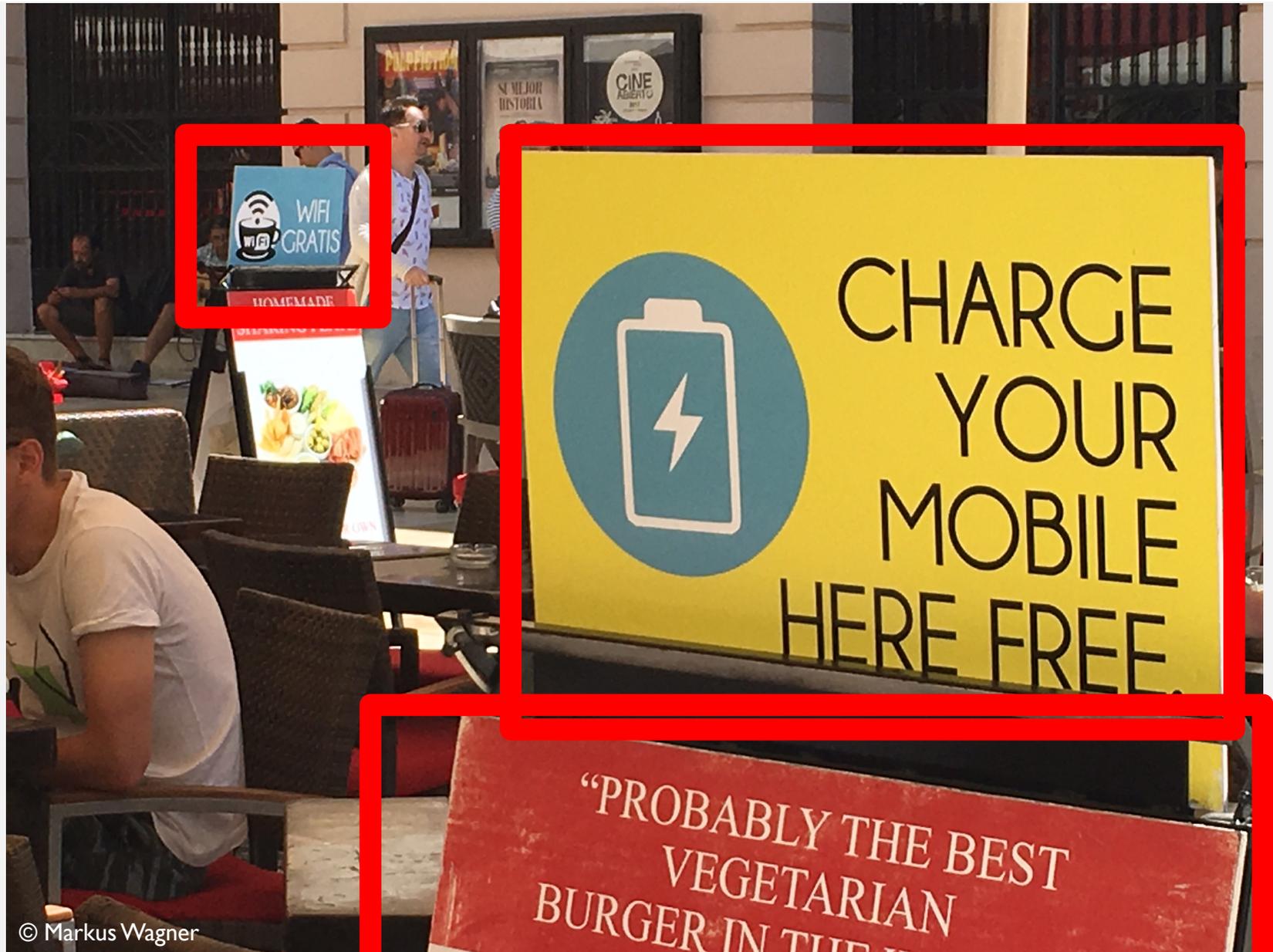
Full paper: <http://cs.adelaide.edu.au/~markus/pub/2017gecco-deepandroid.pdf>

# Maslow's hierarchy of needs 2.0

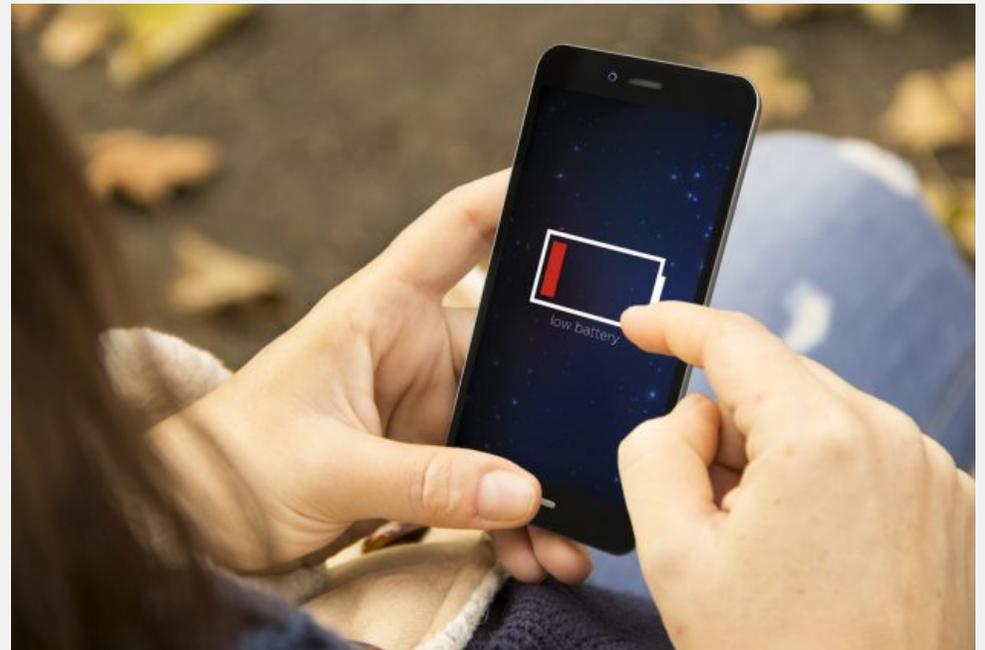


# Maslow's hierarchy of needs

Photo taken in Malaga, July 2017



as soon as this appears



shock



anger



denial



the need to get power



# MOTIVATION

Number of smartphone users ~2 billion



Users expect



Reality

there is a simple solution

# Genetic Improvement

there is a ~~simple~~ solution

# Genetic Improvement

# MOTIVATION

## What do programmers know about the energy consumption of software?

CANDY PANG, ABRAM HINDLE, BRAM ADAMS, AHMED E. HASSAN

## How Do Code Refactorings Affect Energy Usage?\*

Cagri Sahin  
University of Delaware  
United States  
cagri@udel.edu

Lori Pollock  
University of Delaware  
United States  
pollock@udel.edu

James Clause  
University of Delaware  
United States  
clause@udel.edu

## RELATED WORK

### Reducing Energy Consumption Using Genetic Improvement

Bobby R. Bruce  
University College London  
London  
United Kingdom  
r.bruce@cs.ucl.ac.uk

Justyna Petke  
University College London  
London  
United Kingdom  
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Mark Harman  
University College London  
London  
United Kingdom  
mark.harman@ucl.ac.uk

### Optimizing Energy Consumption of GUIs in Android Apps: A Multi-objective Approach

Mario Linares-Vásquez<sup>1</sup>, Gabriele Bavota<sup>2</sup>, Carlos Bernal-Cárdenas<sup>1</sup>  
Rocco Oliveto<sup>3</sup>, Massimiliano Di Penta<sup>1</sup>, Denys Poshyvanyk<sup>1</sup>

<sup>1</sup>The College of William and Mary, Williamsburg, VA, USA — <sup>2</sup>Free University of Bozen, Bolzano, Italy

<sup>3</sup>University of Molise, Pesche (IS), Italy — <sup>4</sup>University of Sannio, Benevento, Italy

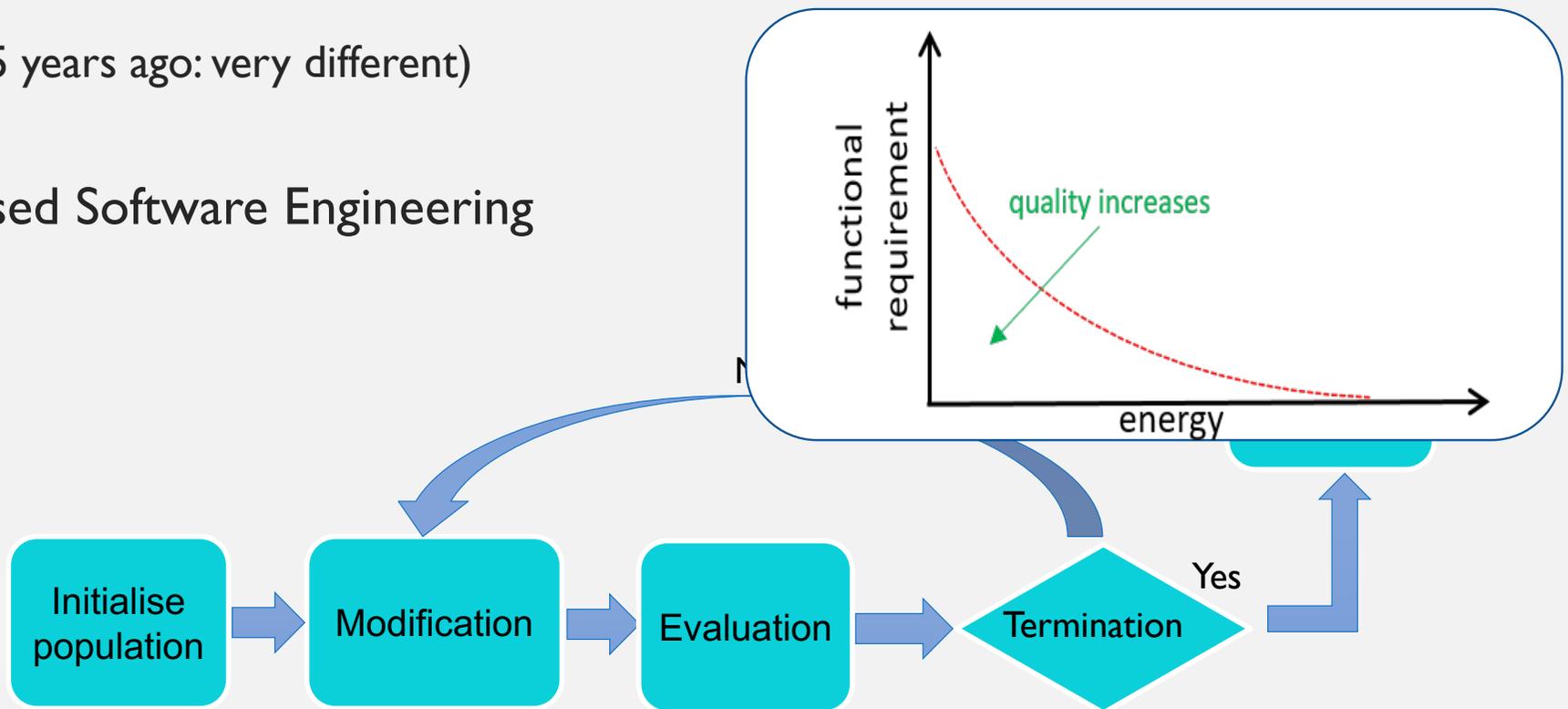
#### ABSTRACT

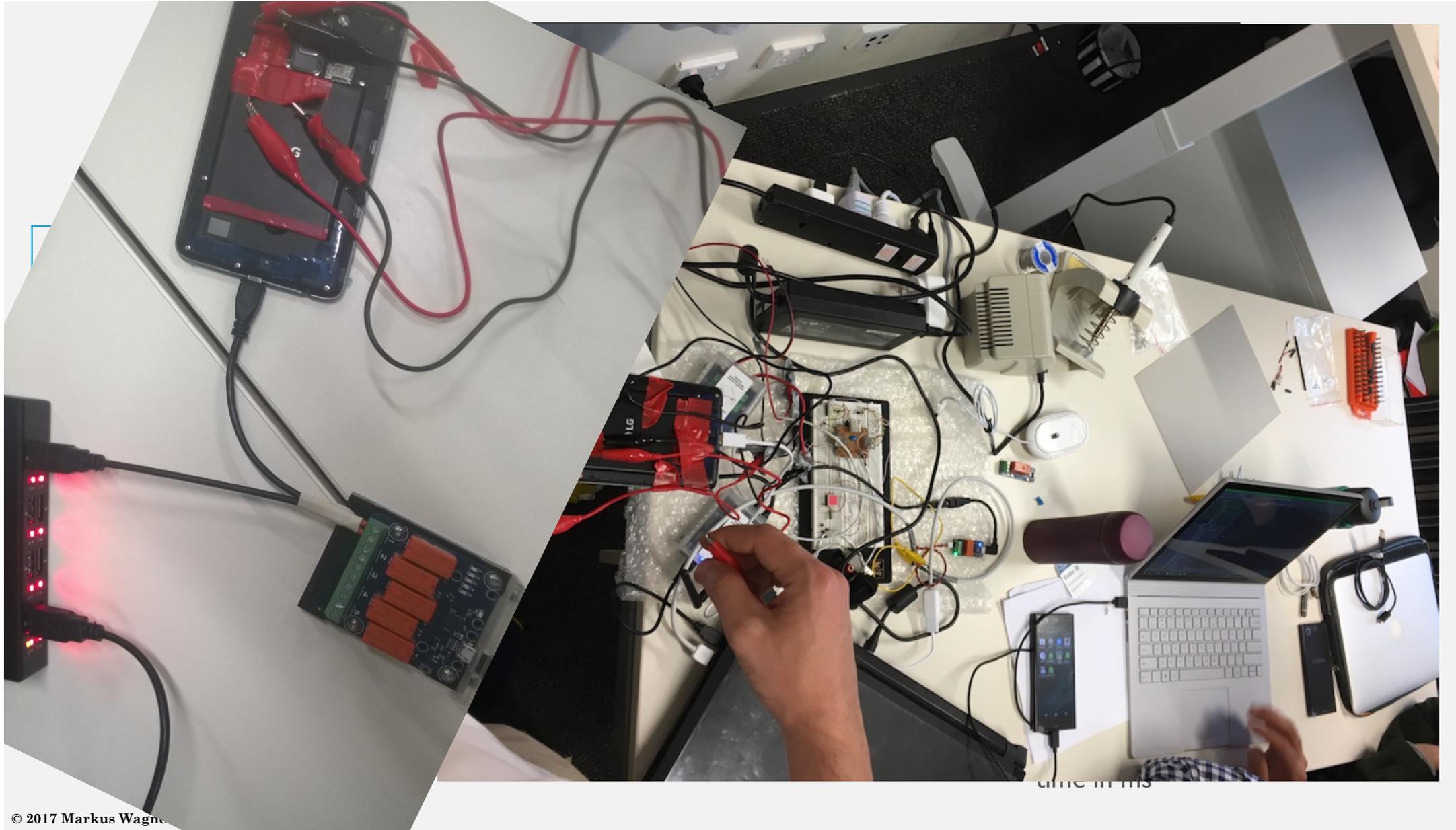
The wide diffusion of mobile devices has motivated research towards optimizing energy consumption of software systems—including apps—targeting such devices. Besides efforts aimed at dealing with various kinds of energy bugs, the adoption of Organic Light-Emitting Diode (OLED) screens has motivated research towards reducing energy consumption by choosing an appropriate color palette. Whilst past research

have been aimed at engineering energy-friendly hardware components in mobile devices, some recent research has also focused on energy-aware development practices for reducing the energy consumption in mobile apps. For instance, common energy bugs in mobile apps have been identified and catalogued [27, 28, 32, 34, 42], as well as typical hot spots [39] together with energy greedy APIs [26, 33]. In addition, several infrastructures and methods have been proposed to measure

# METHODOLOGY

- Energy Measurement
  - External.
  - Internal. (5 years ago: very different)
- Search Based Software Engineering





# TARGET APP

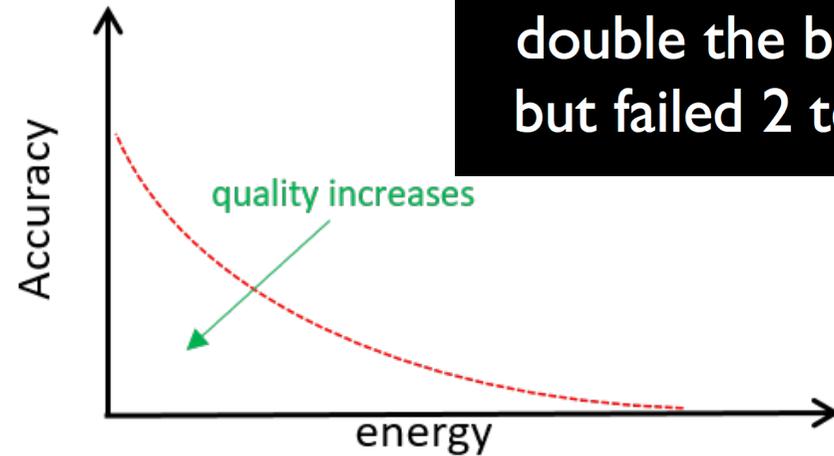
- Requirements:
  - Open source.
  - Widely used.
  - Energy-hungry app.
  - Test suite.

# TARGET APP

- Rebound Library:
  - Open source.
  - Widely used.
  - Energy-hungry app.
  - 44 test cases.
    - Speed and position of springs.



<http://face>

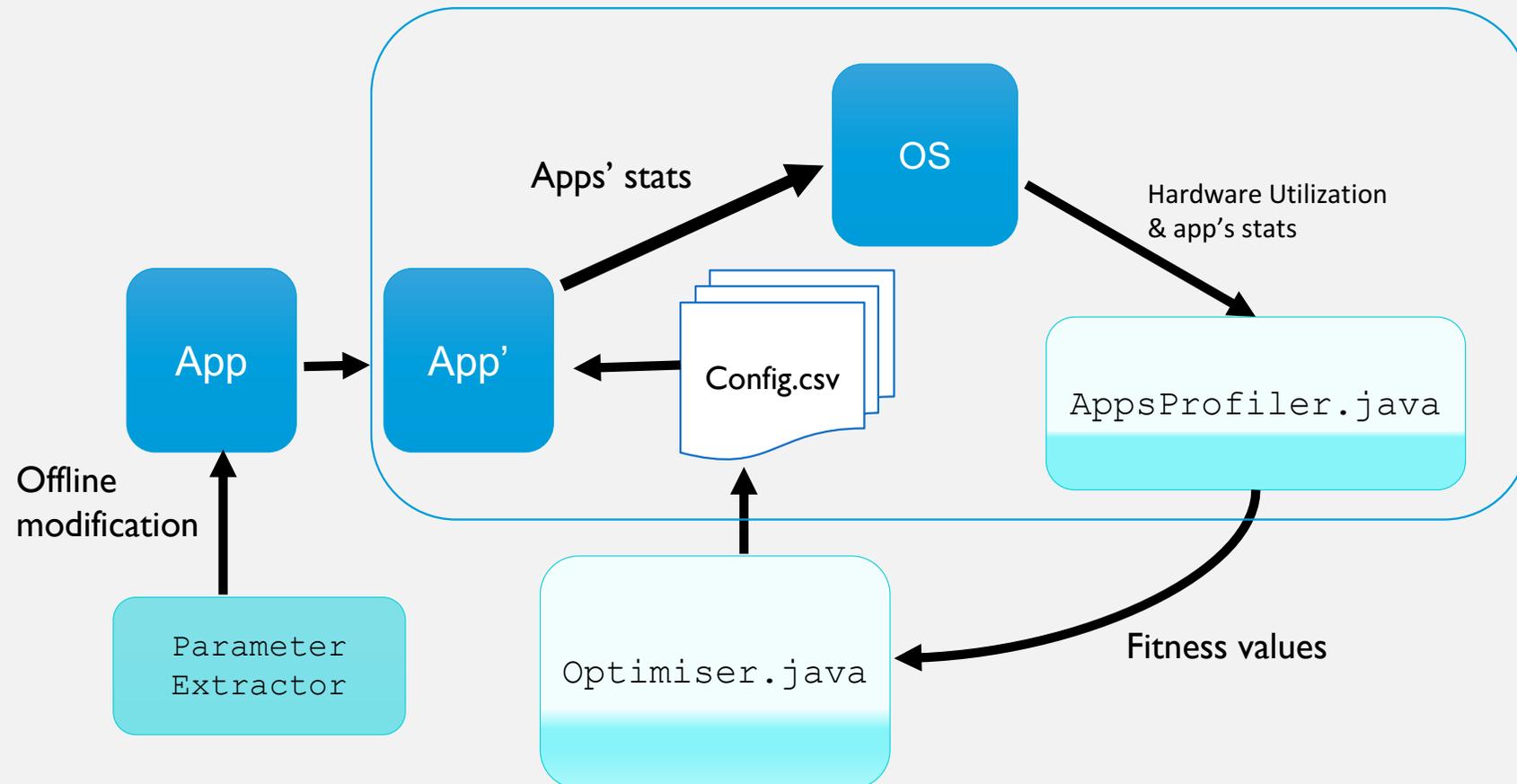


double the battery life  
but failed 2 test cases?

ok Home

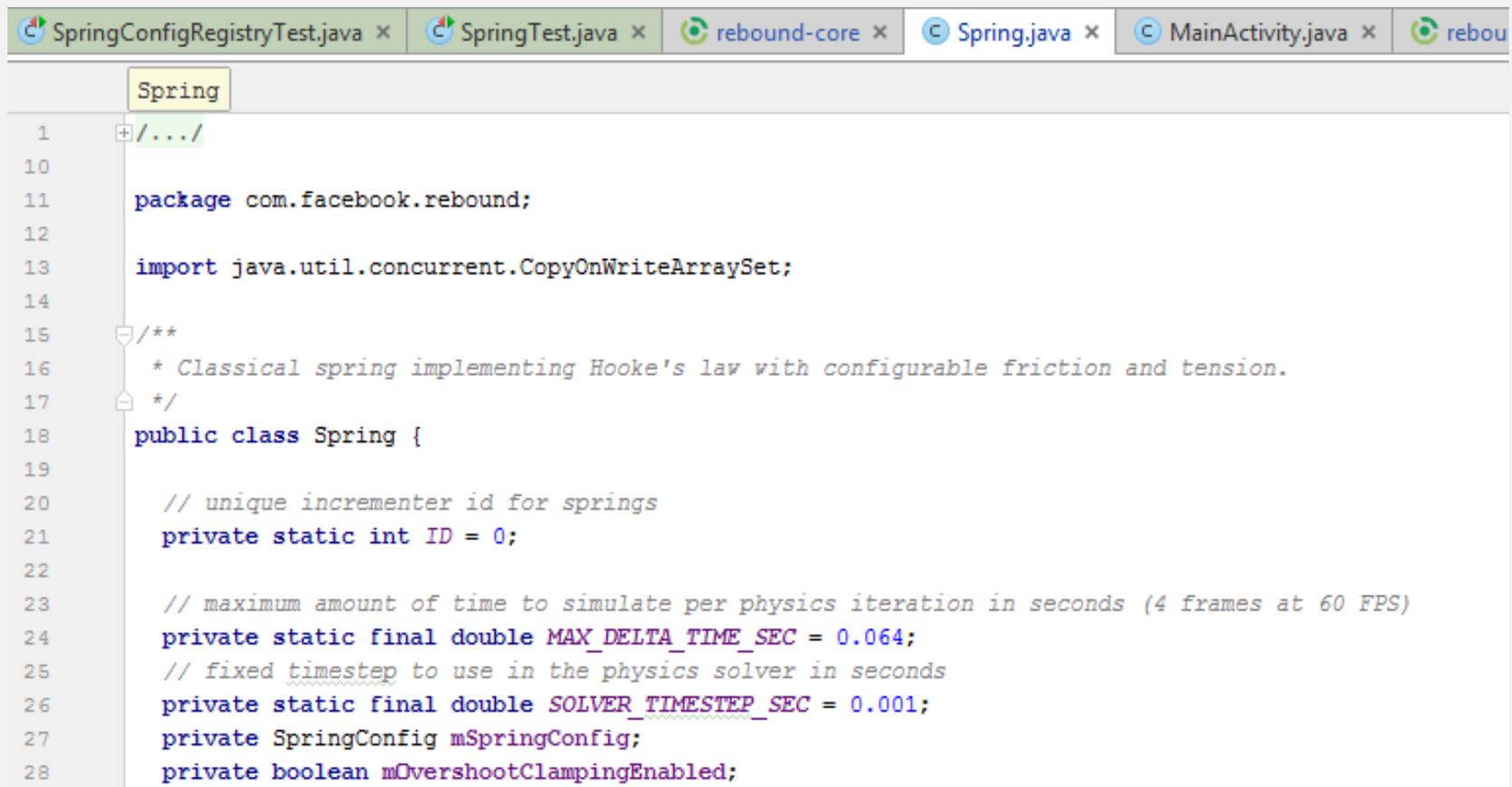
# FRAMEWORK

- Deep Parameter Tuning. → Parameter tuning of the physics calculations!



# FRAMEWORK

- Deep Parameter Tuning. → Parameter tuning of the physics calculations!



```
Spring
1  +/.../
10
11  package com.facebook.rebound;
12
13  import java.util.concurrent.CopyOnWriteArraySet;
14
15  /**
16   * Classical spring implementing Hooke's law with configurable friction and tension.
17   */
18  public class Spring {
19
20     // unique incrementer id for springs
21     private static int ID = 0;
22
23     // maximum amount of time to simulate per physics iteration in seconds (4 frames at 60 FPS)
24     private static final double MAX_DELTA_TIME_SEC = 0.064;
25     // fixed timestep to use in the physics solver in seconds
26     private static final double SOLVER_TIMESTEP_SEC = 0.001;
27     private SpringConfig mSpringConfig;
28     private boolean mOvershootClampingEnabled;
```

# FRAMEWORK

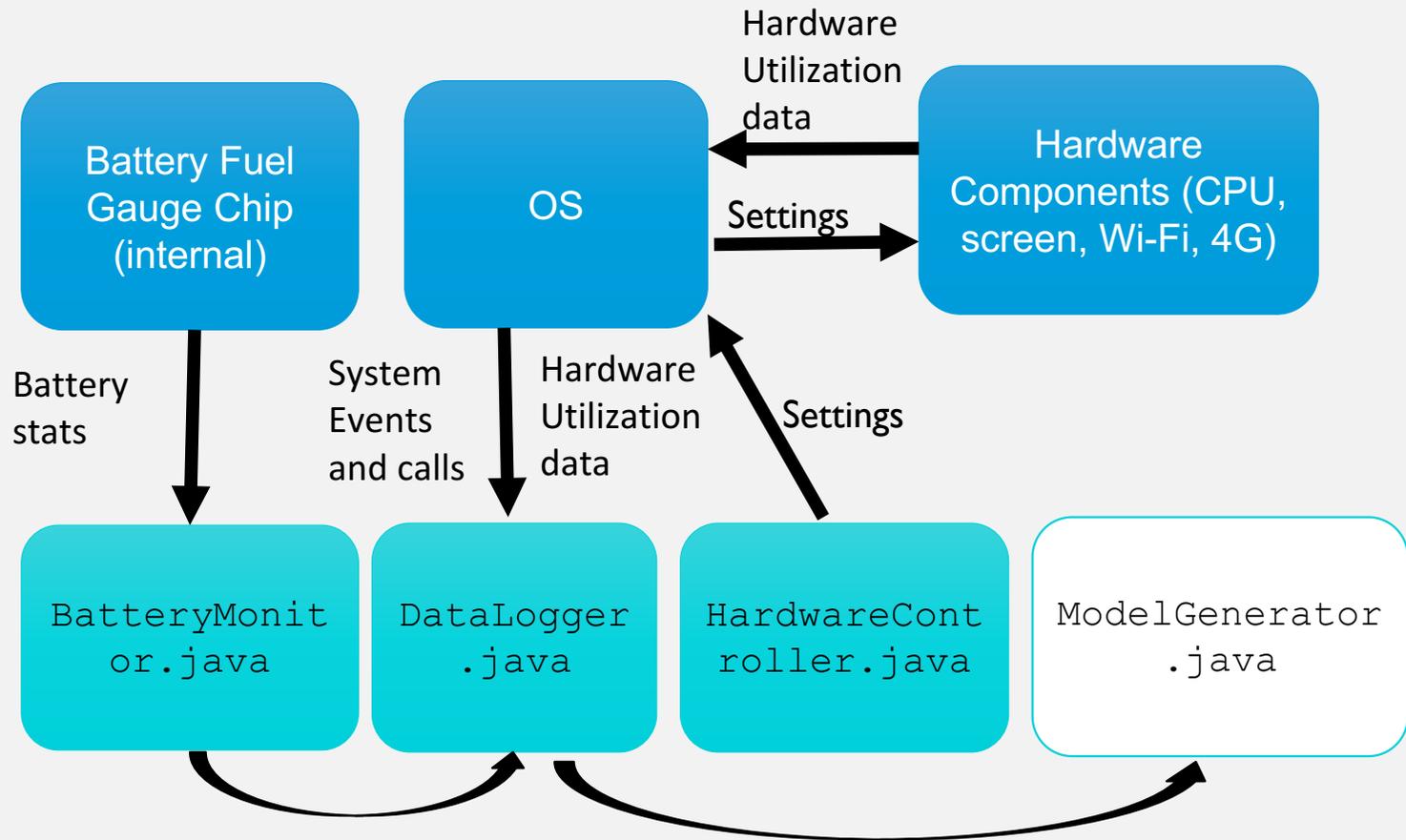
- Deep Parameter Tuning. → Parameter tuning of the physics calculations!

```
ResultRecorder.java x SpringTest.java x Define.java x Spring.java x ModifiedRebound x gradle.properties x InexactComparis
Spring
12
13 import java.util.concurrent.CopyOnWriteArraySet;
14
15
16
17 /**
18  * Classical spring implementing Hooke's law with configurable friction and tension.
19  */
20 public class Spring {
21
22     // unique incrementer id for springs
23     private static int ID = Define.Spring_INTEGER_21_1_0;
24
25     // maximum amount of time to simulate per physics iteration in seconds (Define.Spring_INTEGER_23_1_4 frames at Def
26     private static final double MAX_DELTA_TIME_SEC = Define.Spring_DOUBLE_24_1;
27     // fixed timestep to use in the physics solver in seconds
28     private static final double SOLVER_TIMESTEP_SEC = Define.Spring_DOUBLE_26_1;
29     private SpringConfig mSpringConfig;
30     private boolean mOvershootClampingEnabled;
```

19	Spring_INTEGER_48_1_0	0
20	Spring_INTEGER_23_2_60	57
21	Spring_INTEGER_23_1_4	4
22	Spring_INTEGER_21_1_0	0
23	Spring_INTEGER_2_1_2013	2013
24	Spring_DOUBLE_481_1	0
25	Spring_DOUBLE_377_3	2
26	Spring_DOUBLE_377_2	6
27	Spring_DOUBLE_377_1	1
28	Spring_DOUBLE_376_3	2
29	Spring_DOUBLE_376_2	6
30	Spring_DOUBLE_376_1	1
31	Spring_DOUBLE_366_1	0.5
32	Spring_DOUBLE_365_1	0.5
33	Spring_DOUBLE_361_1	0.5
34	Spring_DOUBLE_360_1	0.5
35	Spring_DOUBLE_47_1	0.005
36	Spring_DOUBLE_46_1	0.005
37	Spring_DOUBLE_26_1	0.001
38	Spring_DOUBLE_24_1	0.064

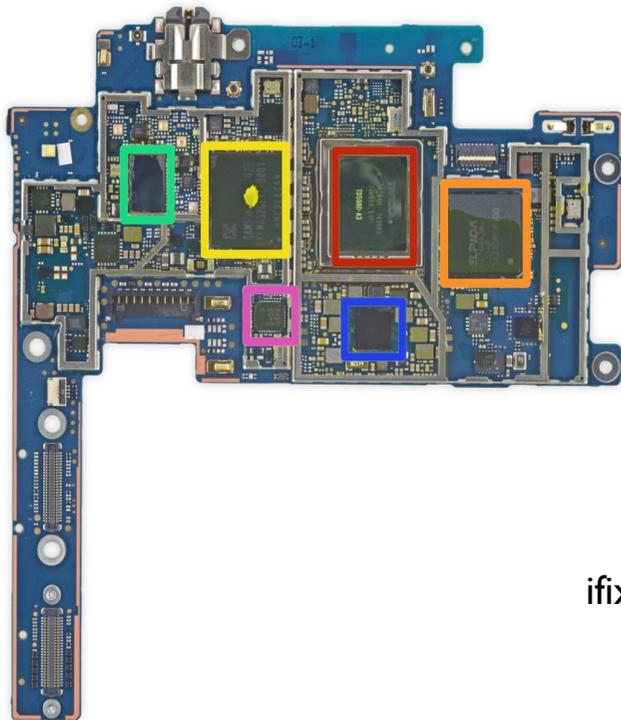
# METHOD

Hardware Data:  
CPU freq., Screen  
brightness,  
transmitted packets,  
signal strength ...  
36 dimensions  
(CPU, Screen,  
Network)  
Software data:  
Apps utilisation.



# CHALLENGES

- Noise.
- System Architecture and Behaviour.



ifixit.com

## APPLICATION LAYER

Native Apps  
(Contacts, Maps, Browser,  
etc.)

Third-Party Apps

Developer Apps

## APPLICATION FRAMEWORK

```
C:\Users\Mahmoud-Uni>adb shell ps
```

```
root    1    0   1624   700  Sys_epoll_0000000000 s /init
root    2    0    0    0    kthreadd_0000000000 s kthreadd
root    3    2    0    0    smpboot_th_0000000000 s ksoftirqd/0
root    5    2    0    0    worker_thr_0000000000 s kworker/0:0H
root    7    2    0    0    smpboot_th_0000000000 s migration/0
root    8    2    0    0    rcu_gp_kth_0000000000 s rcu_preempt
root    9    2    0    0    rcu_gp_kth_0000000000 s rcu_bh
root   10    2    0    0    rcu_gp_kth_0000000000 s rcu_sched
root   11    2    0    0    smpboot_th_0000000000 s watchdog/0
root   12    2    0    0    smpboot_th_0000000000 s watchdog/1
root   13    2    0    0    smpboot_th_0000000000 s migration/1
root   14    2    0    0    smpboot_th_0000000000 s ksoftirqd/1
```

.... 202 processes

Hardware Drivers  
(USB, Display, Bluetooth,  
etc.)

Power  
Management

Process  
Management

Memory  
Management

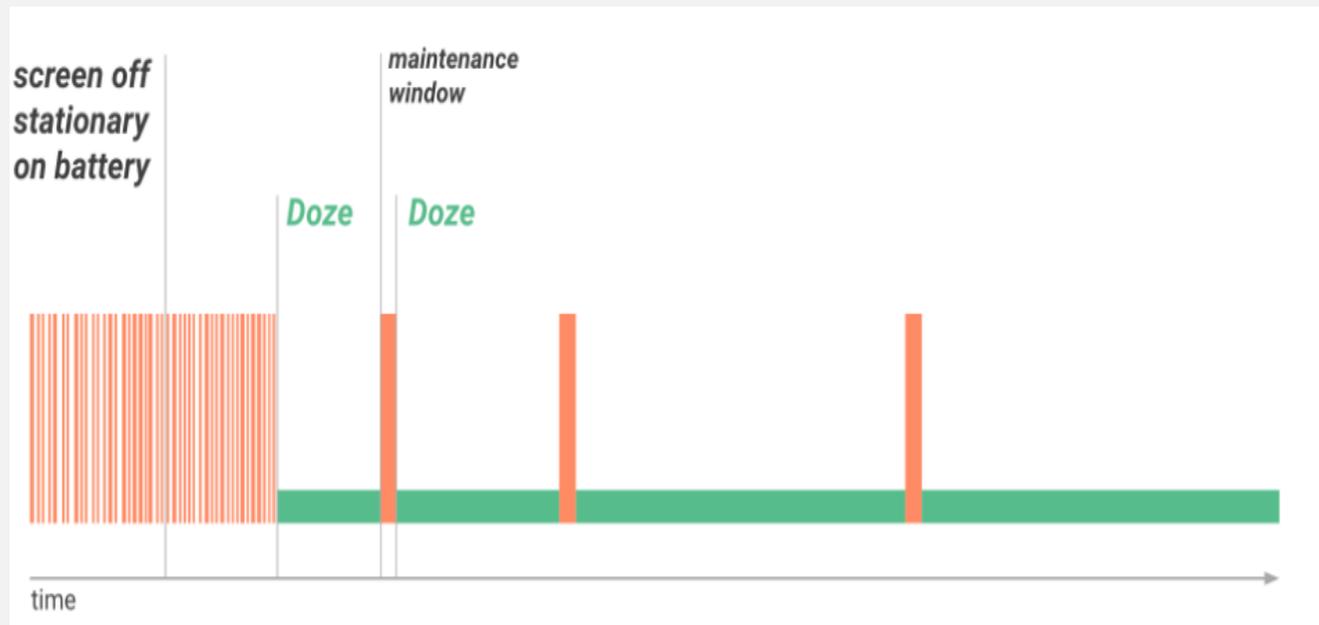


# CHALLENGES

- Noise.
  - System Architecture and Behaviour.
    - Solution.
      - Airplane mode.
      - Changing the CPU governor.
      - Fixing CPU frequency.
      - Turning the screen off.

# CHALLENGES

- Noise.
- System Architecture and Behaviour.
  - Doze Mode.



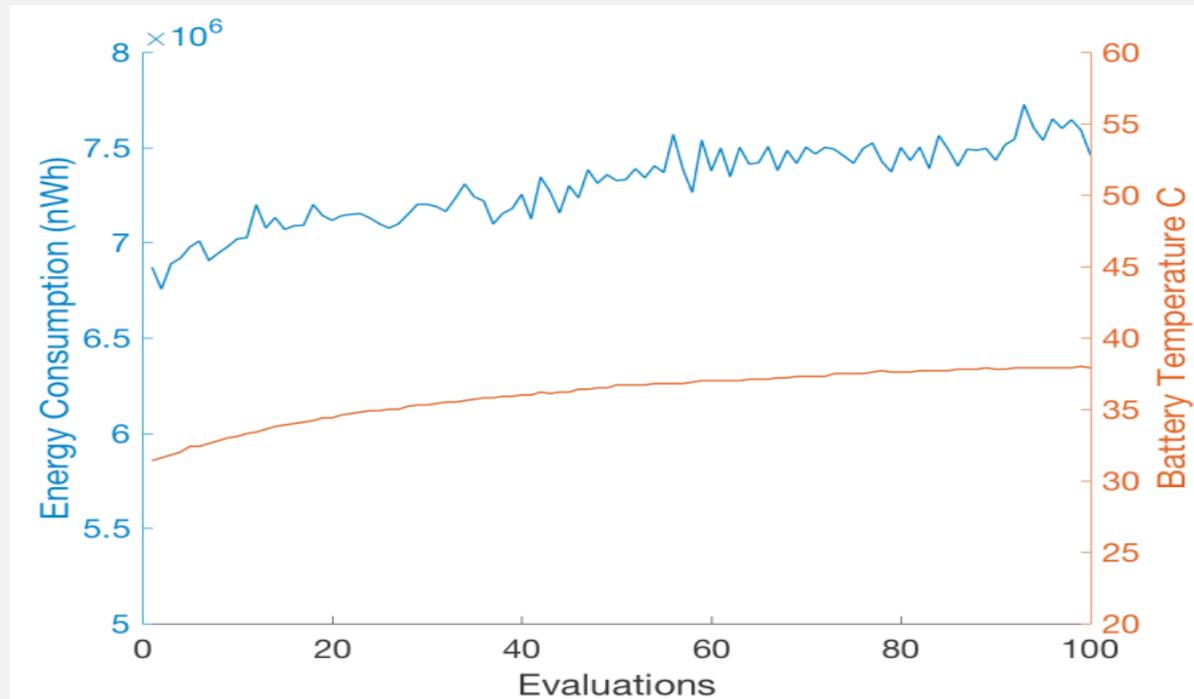
# CHALLENGES

- Noise.
  - System Architecture and Behaviour.
    - Doze Mode.
    - Solution.



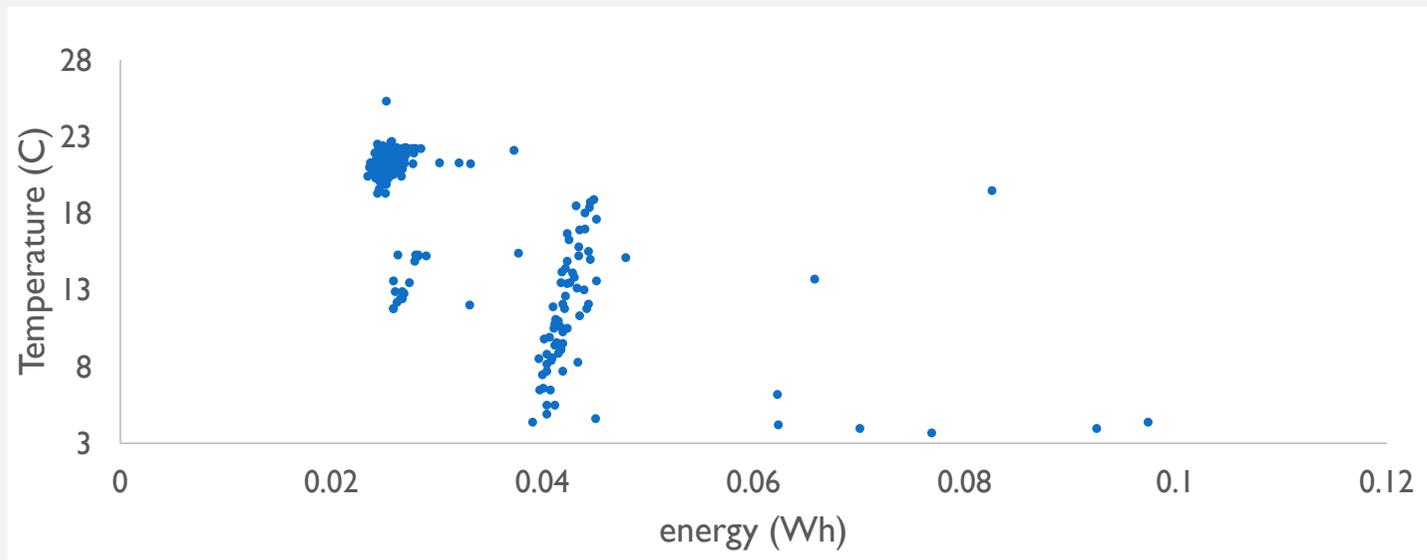
# CHALLENGES

- Noise.
- Temperature.



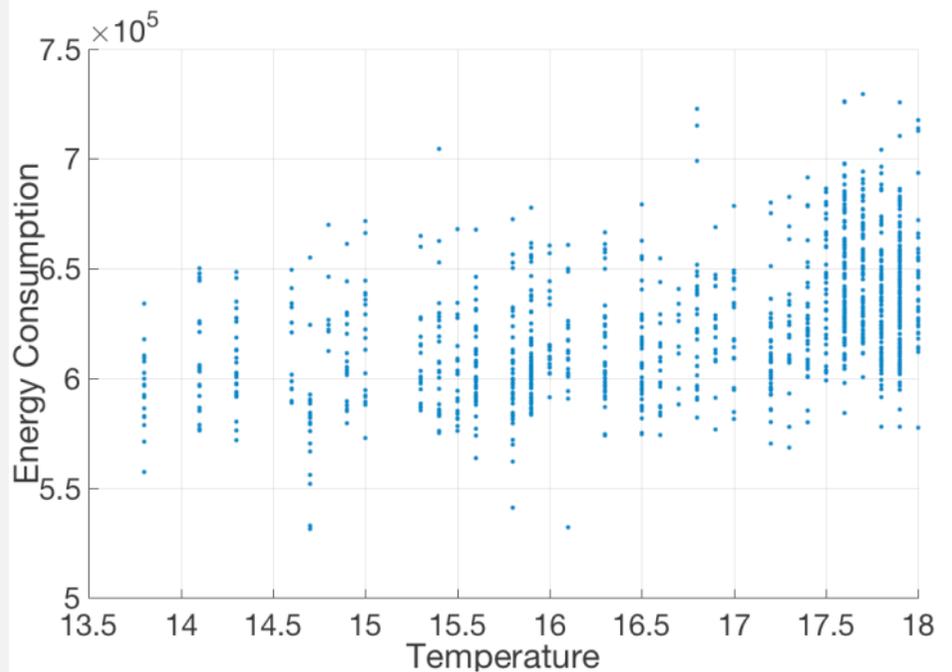
# CHALLENGES

- Noise.
- Temperature.
  - Fridge.

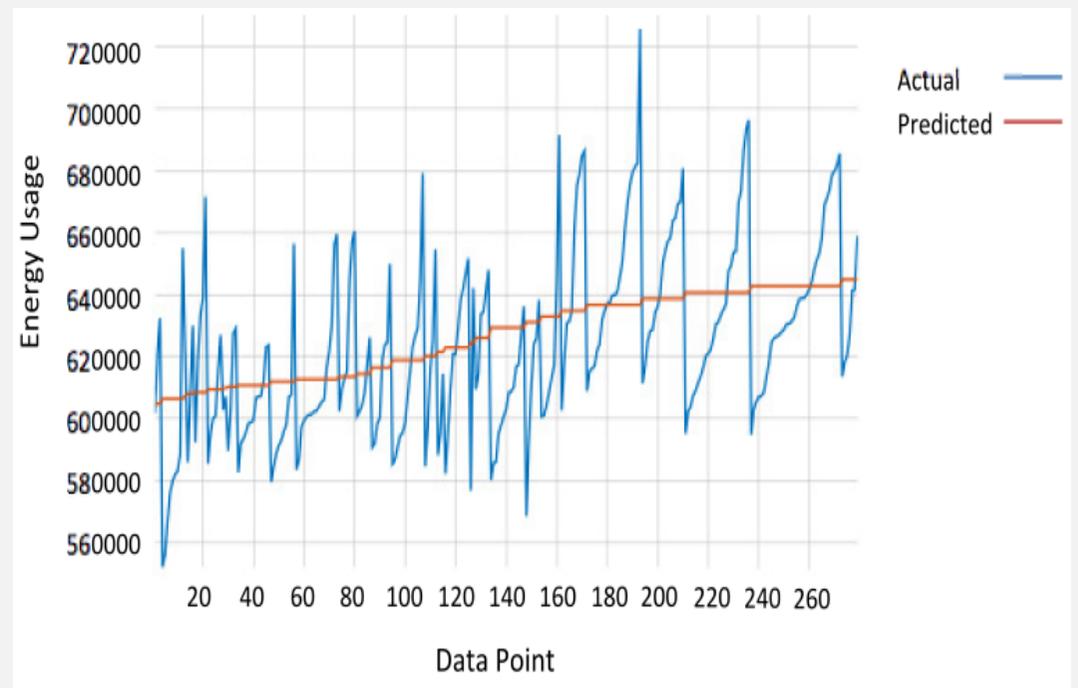


# CHALLENGES

- Noise.
- Temperature.
  - Fridge.
  - Model & compensate?

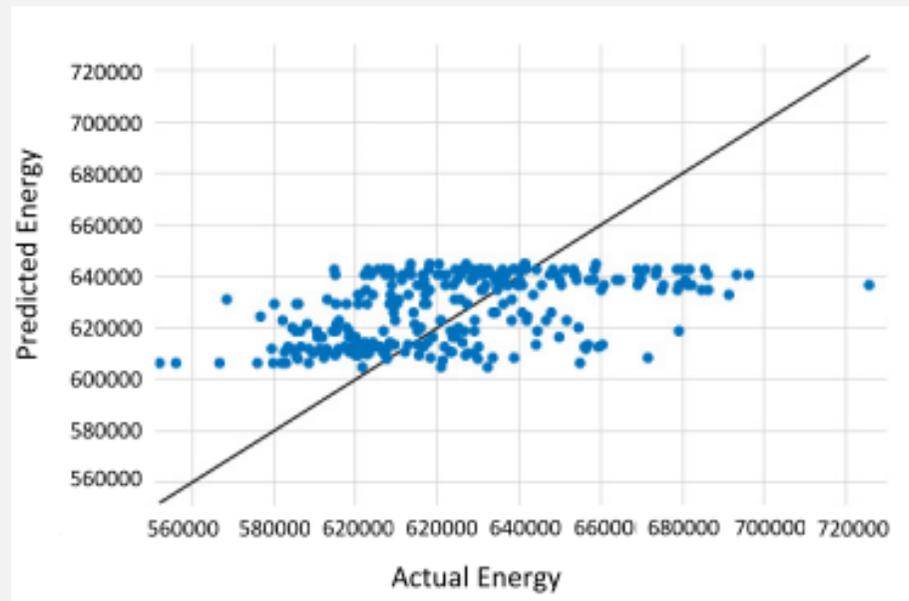


$$e = 357t^2 - 6180.5t + 608000$$



# CHALLENGES

- Noise.
- Temperature.



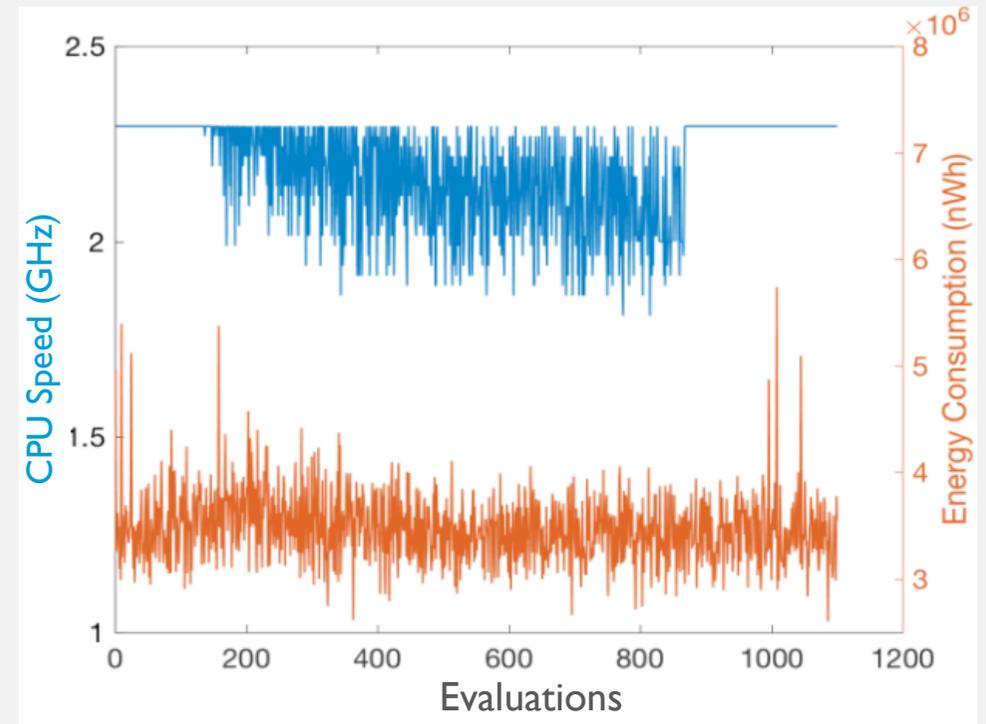
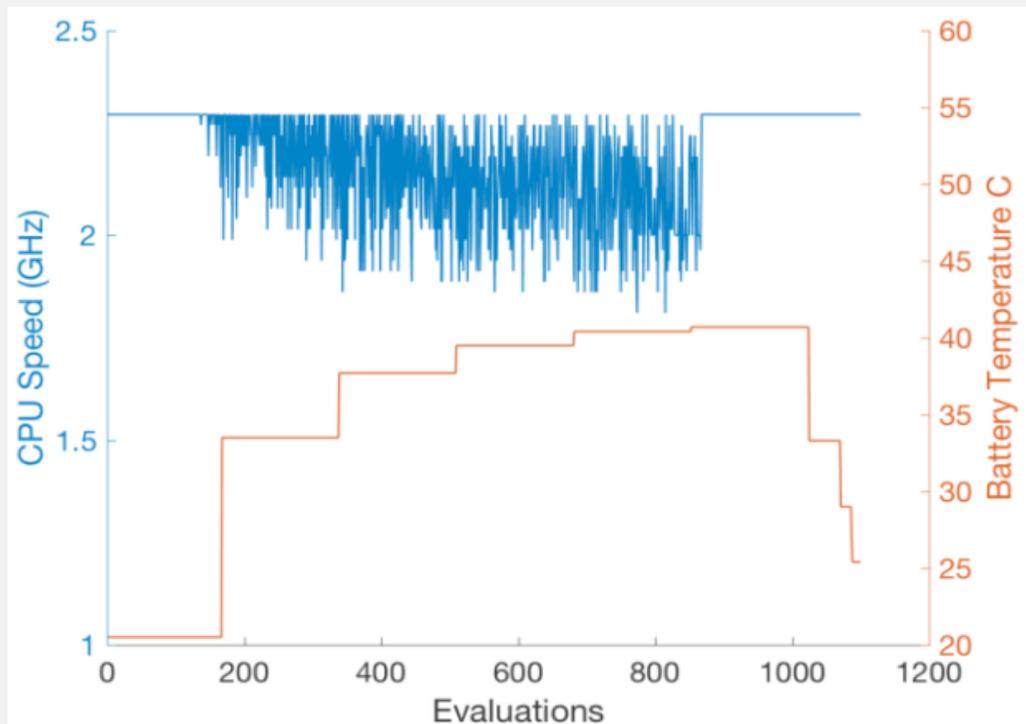
# CHALLENGES

- Noise.
- Temperature.
- Solution.



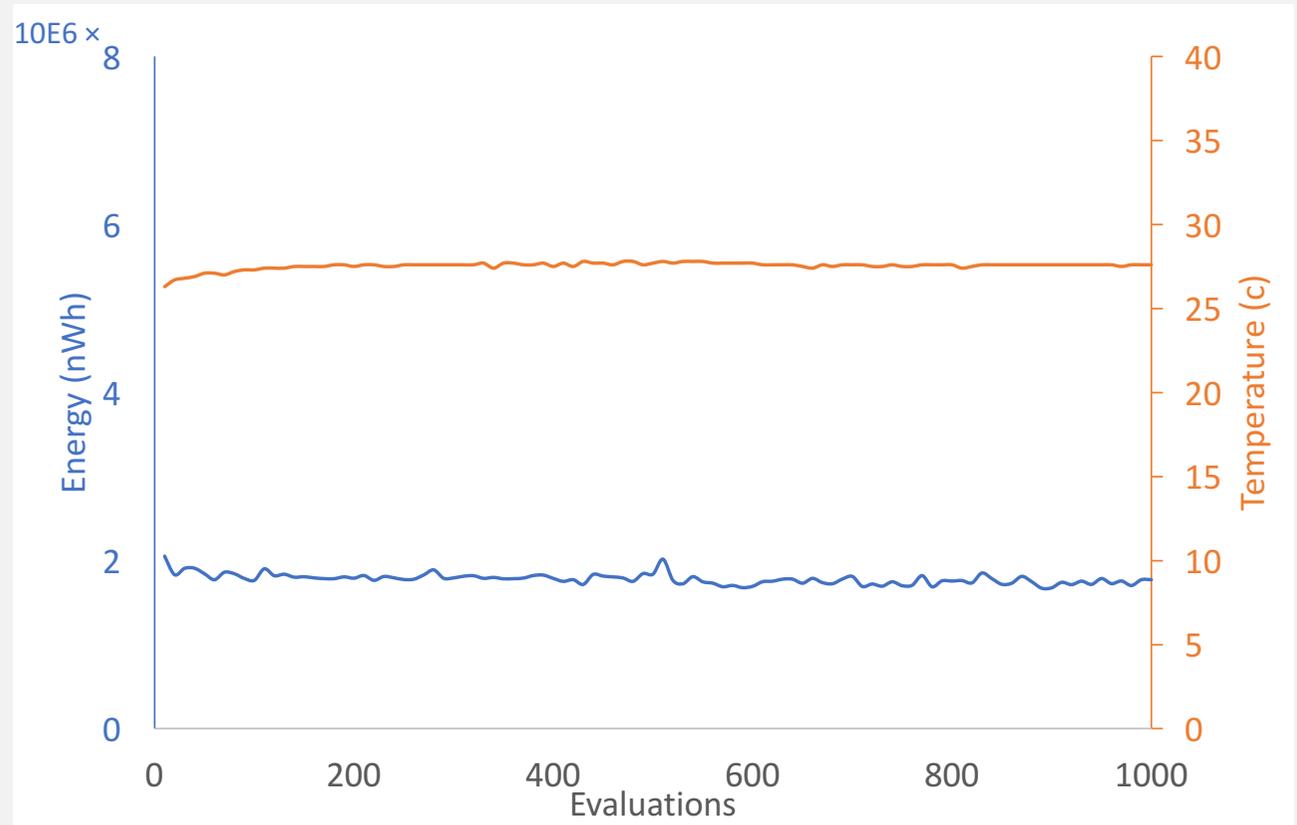
# CHALLENGES

- Noise.
- CPU Throttling.



# CHALLENGES

- Noise.
  - CPU Throttling.
  - Solution.
    - Median frequency: 1.4 GHz.



# CHALLENGES

- Android Debug Bridge.
  - Deployment time.
  - Instability.
  - Connectivity Issues.

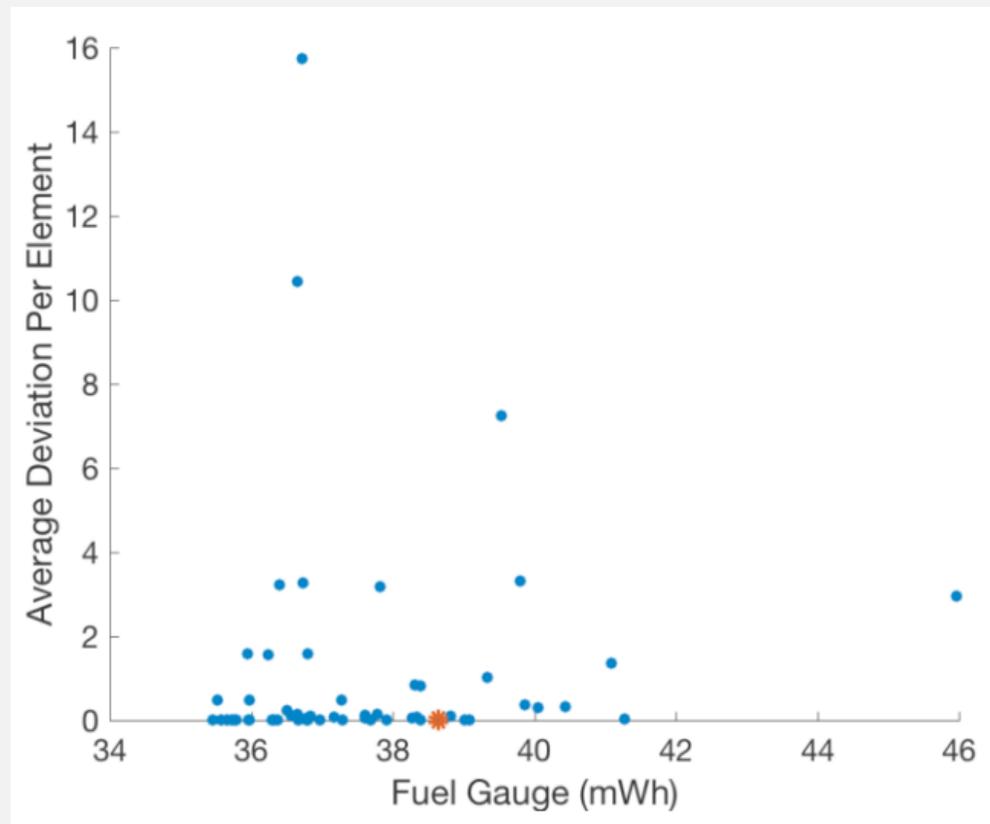


# EXPERIMENT SETUP

- Population size: 20.
  - First population.
- Generations: 17.
- Objectives: Energy & Accuracy.
- Timeout: 2 mins.
- Recharge: 20 mins.
- Measurement frequency: 4Hz.

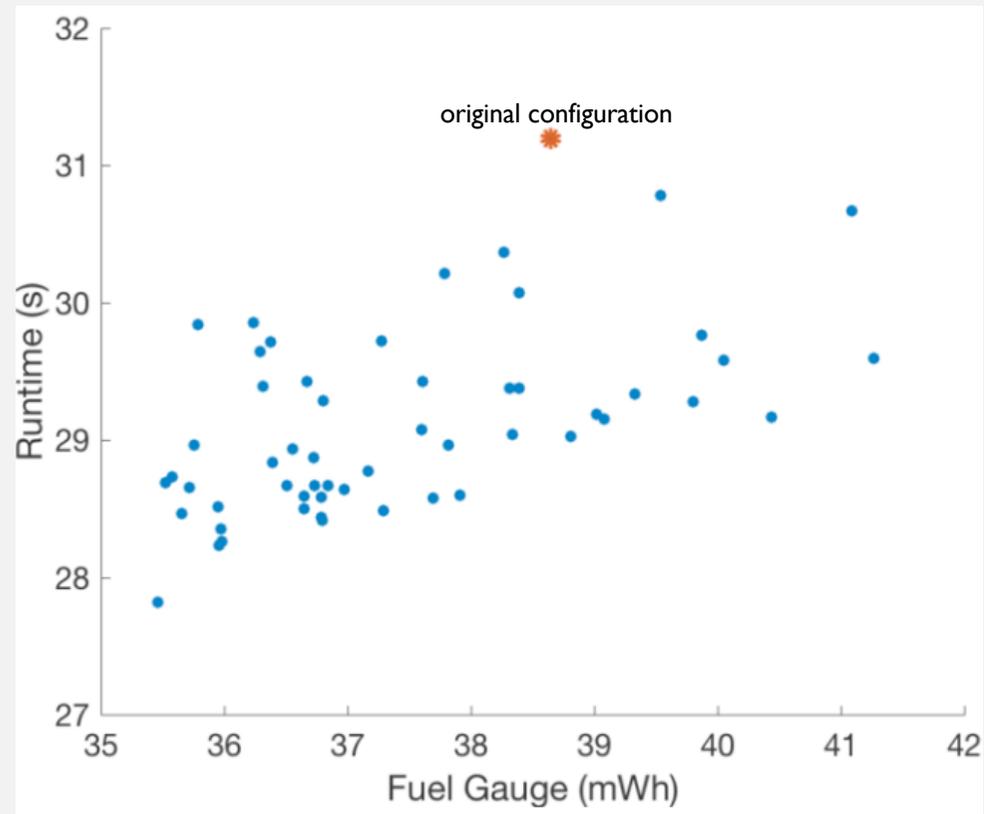


# RESULT



Orange: original configuration

# RESULT



## Summary:

- 1 year of coding and learning
- super “smart” OS and Android tools
- internal sensor: super noisy in short evaluations, pretty good for longer evaluations