Automated Precision Tuning in Activity Classification Systems: A Case Study

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Ageing of Population

Figure: *Umarells*, image courtesy of Wikimedia

How to Help: IoT Devices

- Constant monitoring
- Real-time reactions
- Pervasive technology
- Devices not (or minimally) intrusive

Traditional Issues in the IoT World

Requirements of IoT requires to leverage several trade-offs

- Battery Life .... Computing Performance
- HW Simplicity .... HW Capabilities

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Approximate Computing: Precision Tuning

- Fixed point . . . . Floating Point

Activity Classification for Fall Detection

- *umarell* wears IoT device
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- machine learning classifier continously process sensor data
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Classification System Composition

We consider a state-of-the-art approach for data collection and classification [1]

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- Features are normalized, then labeled by KNN algorithm
- We enable classification to run *locally* instead of offline
  - Network connection may be unavailable
  - Offline identification of the problem may be too late

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Precision Tuning

Goal Avoid floating point processing: use fixed point instead

Knowledge Input normalization

Error Number of mispredictions

Precision Tuning Framework

Two classes of precision tuning frameworks

Static Analysis
Requires Code Annotations

Profinling & Dynamic Analysis
Requires Code Instrumentation

Two classes of precision tuning frameworks

Static Analysis

Tuning **A**ssistant for **F**loating point to **F**ixed point **O**ptimization

Required annotations

TAFFO requires developers to put hints about runtime variables ranges. Annotations are used to specify them:

```
double minSMV
__attribute((annotate("scalar(range(-25,25))")));
```

- *minSMV* will be converted into fixed point representation, numerical range at runtime: $[-25, 25]$.

- STM3220G-EVAL board
  - ARM Cortex M3
  - 16 Mbit of SRAM
  - no FPU
- IDM-8351 digital multimeter

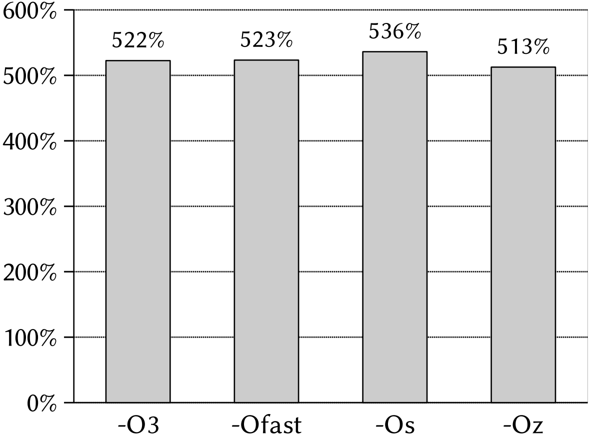
SW setup

IoT devices typically require ad-hoc software systems that have to adapt to specific HW configurations.

- We reproduce this scenario using the real-time operating system MIOSIX[2].
- We compile our code using LLVM and CLANG version 8.0.1
  - using different optimization levels: *-O3 -Ofast -Os -Oz*
- Measure 100 iterations time-frame

[2] miosix.org

Results: Speedup TAFFO vs original



Results: Energy

Tool	Option set	Size [KiB]	T [ms]	$I_{\mu C}$ [mA]	$V_{\mu C}$ [V]	P [mW]	E [mJ]
TAFFO	-O3	39.67	366.5	36.25	3.23	117.1	42.9
	-Ofast	39.79	366.0	36.25	3.23	117.1	42.9
	-Os	39.68	366.3	36.11	3.23	116.6	**42.7**
	-Oz	33.26	384.7	35.88	3.23	115.9	44.6
vanilla	-O3	40.35	2281.3	35.54	3.23	114.8	261.9
	-Ofast	41.39	2281.2	35.83	3.23	115.7	264.0
	-Os	31.53	2330.0	35.87	3.23	115.9	270.0
	-Oz	31.13	2356.6	35.67	3.23	115.2	271.5

Conclusions

Fixed Point enable the use of devices without HW FPU.

- Saving battery life
- Enabling more frequent monitoring
  - Potentially activating effective countermeasures (such as air bags)

Future Work

- Energy characterization of each device component
- Explore alternative classification algorithms
- Explore other machine learning use-cases

Thanks for your attention.

Questions?