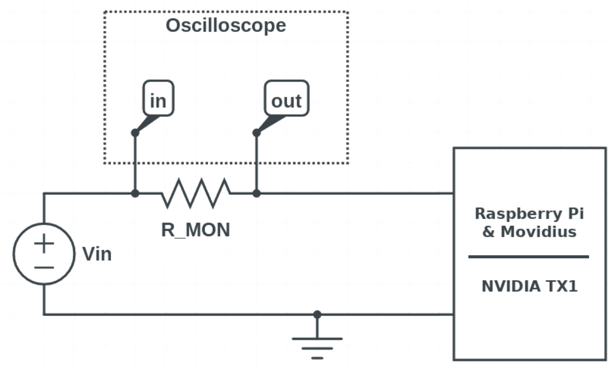
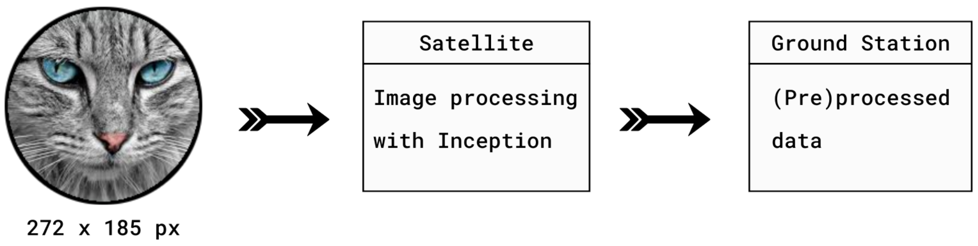
Using AI onboard of small satellites

Open Source Cubesat Workshop 2018 - ESAC (Madrid)

Setup for measurements





For the comparison to be fair we executed the same algorithms on the two platforms.

The chosen algorithm was Inception, a deep-learning-based image classifier withimplementations available for several platforms.A similar algorithm could be trained on groundand embedded to segment and classify satelliteimagery.

NOTE 1: The goal of the reaserch is not to obtain the mostaccurate power consumption measurements, but the figures areaccurate enough to get an idea of what can be done in a Cubesatand what not.

NOTE 2: We've substracted the static current consumption of thesystem (i.e. the current drained when inference was not running).

NOTE 3: The differences between all the versions of Inception are not straightforward. What really matters for us is that each version is more complex and has more layers than the previous one

Intel Movidius

Inception benchmarks

	Inception v1	Inception v2	Inception v3	Inception v4
Confidence (%)	73.8	58.6	59.8	91.4
Latency (ms)	88.4	119.7	317.3	635.8
Max FPS	11.3	8.4	3.2	1.6
Energy per inference (uAh)	30.3	42.2	133.8	231.2
Peak power (mW)	7933.6	8256.6	8160	8507.8

Battery consumption analysis

Batt capacity		Inception v1	Inception v2	Inception v3	Inception v4
500 mAh	Num. of inferences	16516	11835	4338	2162
	Battery duration (min)	24	23	22	22
1000 mAh	Num. of inferences	33033	23671	8677	4325
	Battery duration (min)	48	47	45	45
1500 mAh	Num. of inferences	49550	35507	13016	6488
	Battery duration (min)	73	70	68	68

NVIDIA TX1

Inception benchmarks

	Inception v1	Inception v2	Inception v3	Inception v4
Confidence (%)	73.4	36.9	57.6	
Latency (ms)	92.7	119.9	209.219	
Max FPS	10.8	8.4	4.8	
Energy per inference (uAh)	5.74	6.801	12.7	
Peak power (mW)	4326.7	5174.3	5098.5	

Battery consumption analysis

Batt capacity		Inception v1	Inception v2	Inception v3	Inception v4
500 mAh	Num. of inferences	87061	73517	39348	
	Battery duration (min)	134	146	137	
1000 mAh	Num. of inferences	174123	147034	78697	
	Battery duration (min)	268	293	274	
1500 mAh	Num. of inferences	261185	220552	118045	
	Battery duration (min)	403	440	411	

[1]The peak power consumption of Inception v4 was too high and due to limitations with our setup it could not be measured.

Conclusions

- The Intel Movidius is much more power hungry than the TX1.
- The NVIDIA TX1 can achieve higher FPS, however it's far from using it on live video.
- Inception v2 yields bad results.
- The NVIDIA TX1 seems to be very promising for battery powered applications and thus for onboard processing.
- With the NVIDIA TX1 we can run inference on +80k images with only 500 mAh of energy.
- Using an ARM Cortex M (with uTensor) seemed very promising when we started, however, using this framework for image classification is not possible yet.

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+info https://github.com/crespum/oscw18-edge-ai/

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Motivations

- Number of small sats and constellations increasingly growing.
- Embedded devices are getting more powerful and efficient **(edge computing)**, which opens an opportunity for Cubesats to reach an unprecedented level of autonomy.
- There are many solutions in this market but it's difficult to compare them on paper.
- Reveal how propriotary hardware behave so that anyone creating open source computing hardware can compare and have key performance indicators.

Applications

We can leverage AI to react faster, reduce data link usage and in general increase spacecraft's autonomy. Some more specific scenarios are:

- Automate satellite operations.
- Identify complex time-series and detect anomalies in telemetry.
- Analyze data onboard.
- Autonomous coordination of sat constellations
- Deep space missions.

(Write down your ideas below)

Join the workgroup session "Satellite On-Board Artificial Intelligence" with Xabier Crespo to discover more applications.

Improving this research?

- Use resistors smaller and with less tolerance.
- Configure the oscilloscope to use more significant figures when exporting data as well as to increase the number of samples.

Some engineers are using +1000€ wattmeters to measure how many pJ each mathematical operation of a DL network takes. With improvements mentioned above we could obtain those kind of measurements with a relatively low cost setup (~300€).

Future work

- Obtain some telemetry data and use this hardware to analyze it and detect anomalies.
- Run Inception on an ARM M4 processor using uTensor. Convolution is not supported yet but the project is open source.
- Find a challenging battery-powered project that we can solve using this hardware (maybe something for NASA's Space Apps Challenge).

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