Performance of a Smartphone-based Star Tracker

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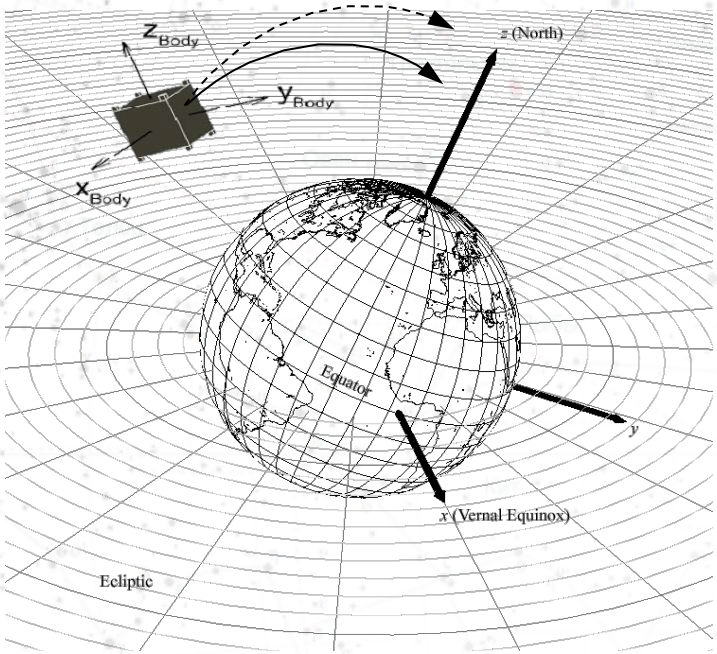
Imperial College London, UK

Research details

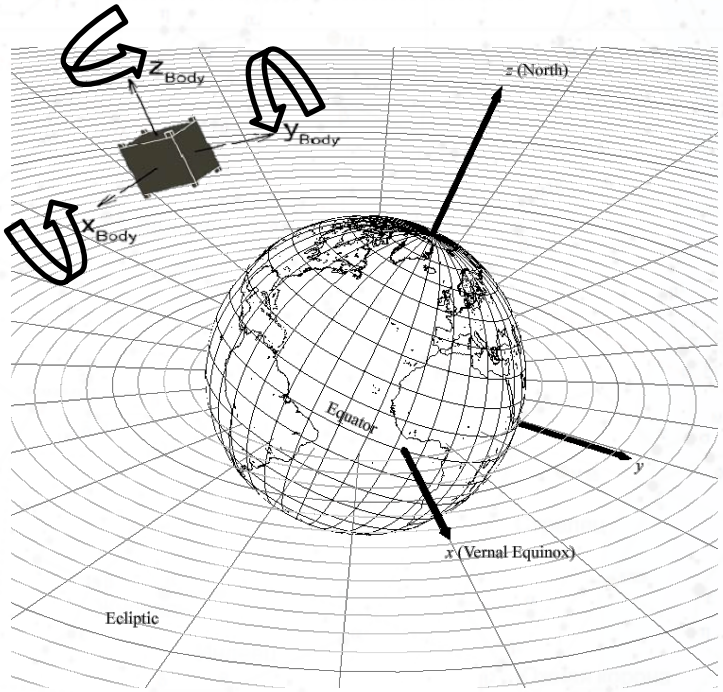
Research topic	Development and evaluation of a miniature Star Tracker for nanosatellite application
Ph.D. student	Andrey Khorev
Ph.D. advisors	Lionel Torres (LIRMM) Eric Nativel (IES)
Started	November 2013
Sponsored by	Van Allen Foundation

Orbit and attitude control of a SC



Orbit control

- Altitude
- Inclination
- Orbit shape and phase



Attitude control

- 3-axis stabilization modes
- Transitions between modes
- Custom 3-axis rotations

Star Tracker as an attitude sensor

Other sources for information about attitude:

– Sun sensor

– Magnetometer (Earth's magnetic field)

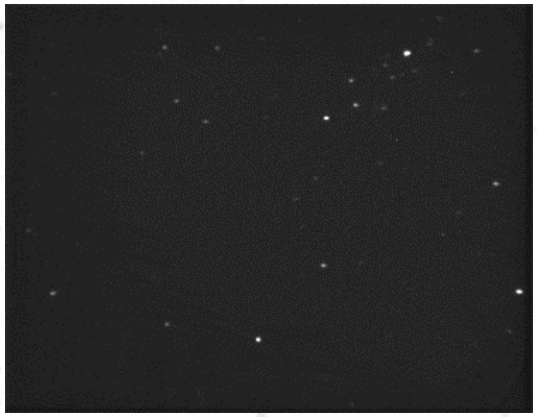
– Earth's IR sensor

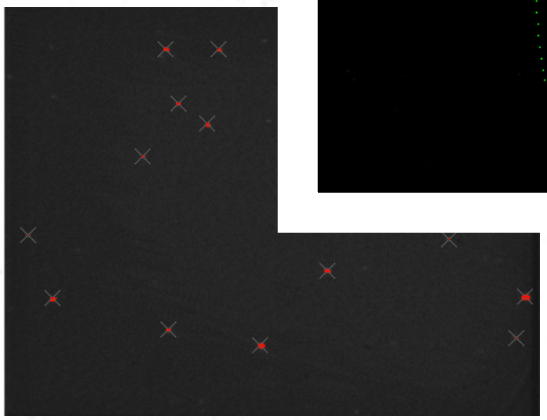
Star Tracker principle of operation

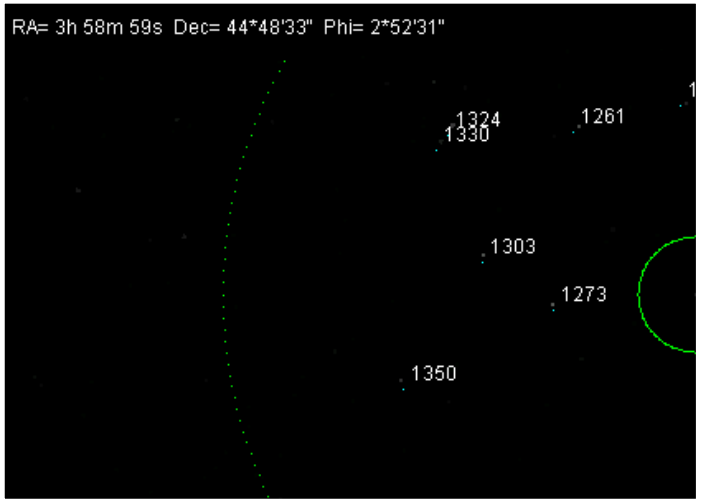
Capture → Extract → Match → Calculate

Modes:

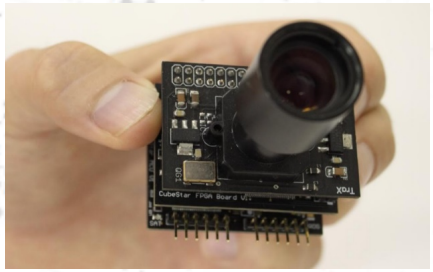
- Tracking
- Lost-in-space
- High angular velocity





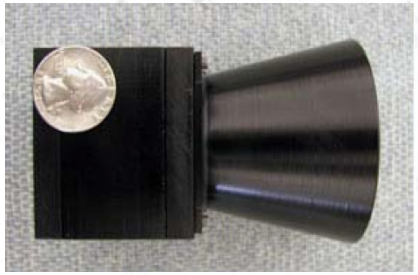


Miniature Star Trackers



CubeStar

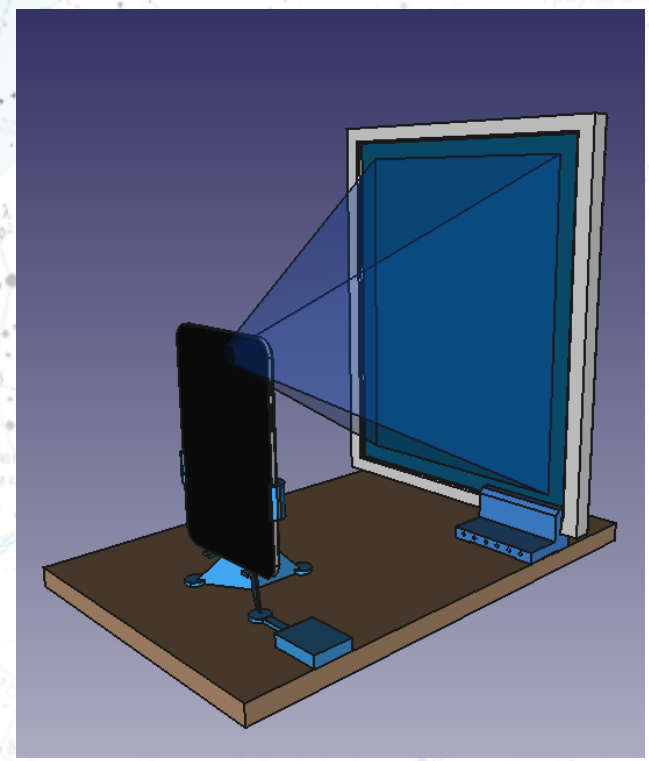
STELLA

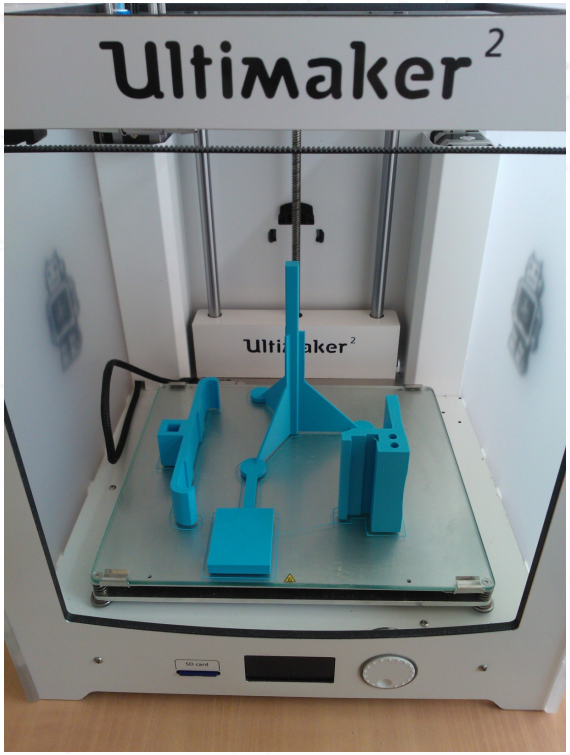


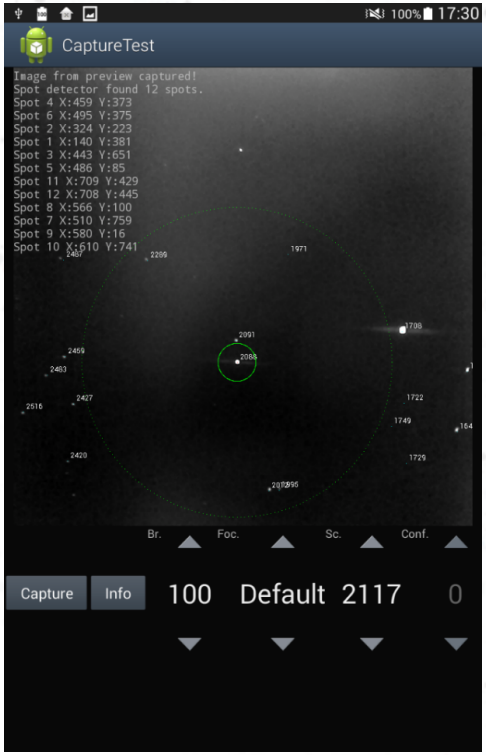
AeroAstro

	Accuracy	Initial acquisition time	Update rate	Size	Weight w/o baffle	Power consumption	Tracking mode	Angular velocity mode
Altair HB+	10”	n/a	1Hz	L	≈ 2.1 kg	12 W	Yes	No
SED26	**3”**	**n/a**	**10 Hz**	**L**	**3.1 kg**	**9.0 W**	**Yes**	**Yes**
Terma	1”	3 (10) s	4 Hz	L	≈ 2 kg	7.0 W	Yes	No
Astrol 15/17	3”	≈ 3 s	22 Hz	M	0.7 kg	5 W	Yes	No
AeroAstro	**70”**	**n/a**	**2 Hz**	**S**	**0.375 kg**	**2.0 W**	**Yes**	**Yes**
BCT	6”	2 s	5 Hz	S	0.350 kg	0.5 W	Yes	No
STELLA	**36”**	**0.25 s**	**4 Hz**	**S**	**0.120 kg**	**0.2 W**	**No**	**No**
<NAME>	**5-10”**	**< 1 s**	**5-20 Hz**	**XS**	**≈ 0.1 kg**	**1-4 W**	**Yes**	**Yes**

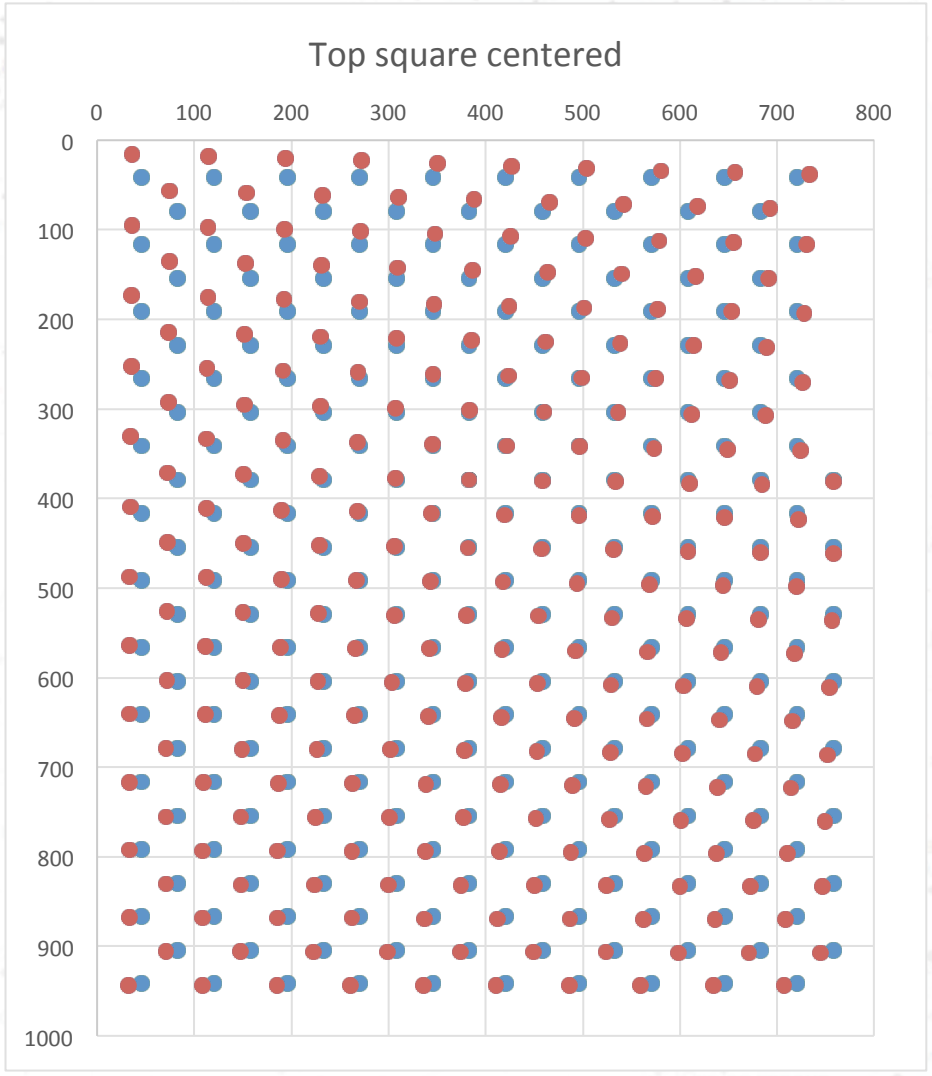
Demonstration setup





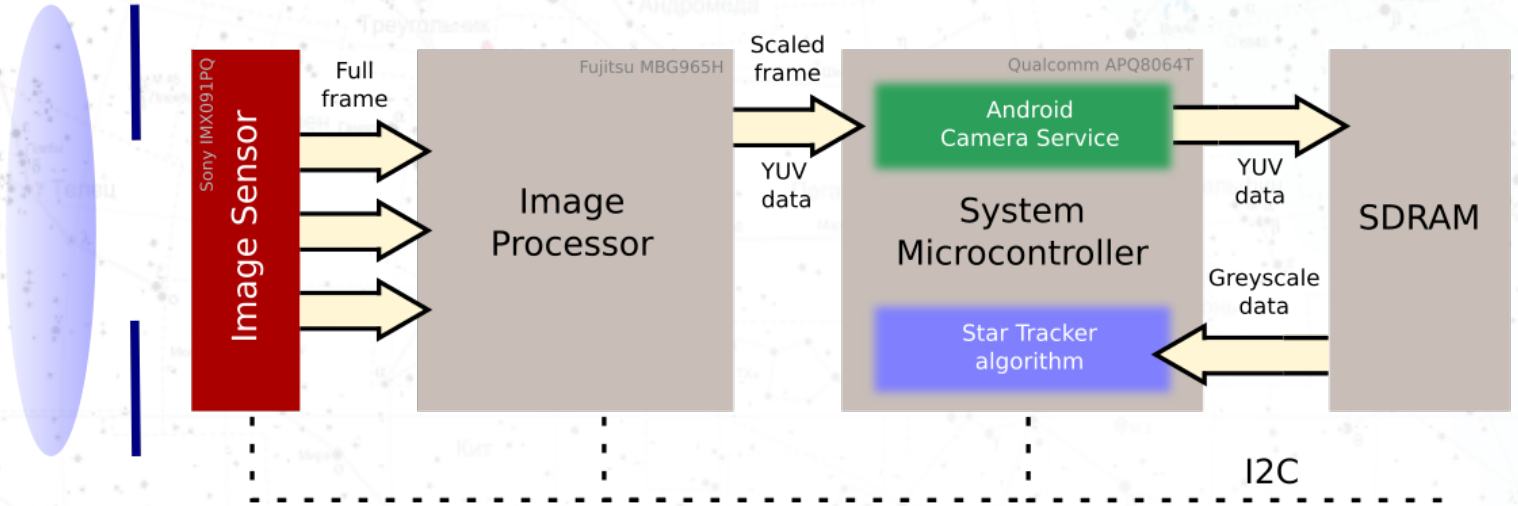


Low-end camera problems



1. Poor light sensitivity
   - Aperture size
   - Color filters
   - Pixel wiring
   - Amplifier noise
2. Low frame rate
3. Optical distortions and manufacturing defects

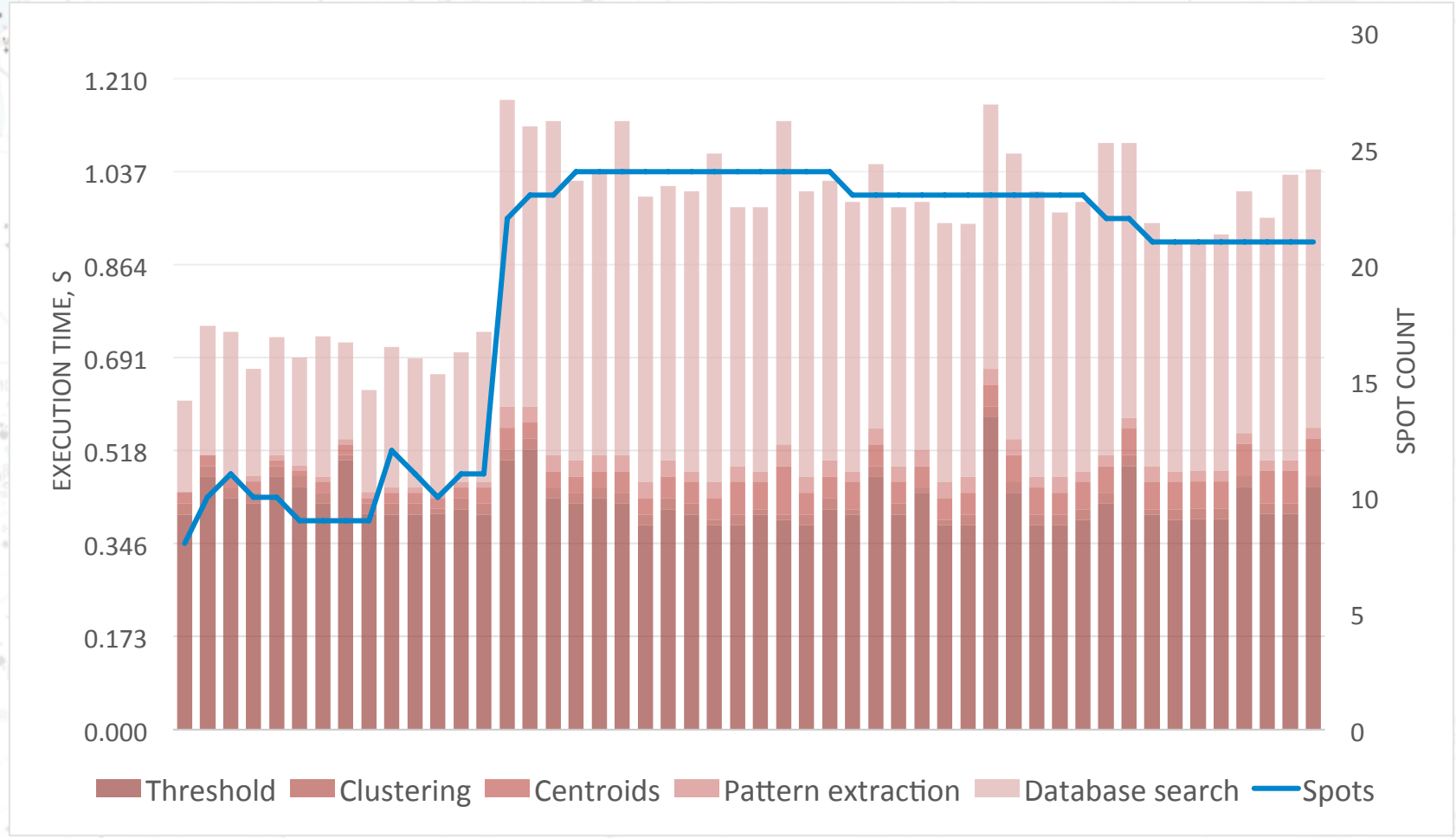
Smartphone hardware



FOV	69˚
Focus length	4.2 mm
Aperture	*ƒ*/2.2
Sensor	Sony IMX091PQ
Dedicated ISP	Fujitsu M10MO

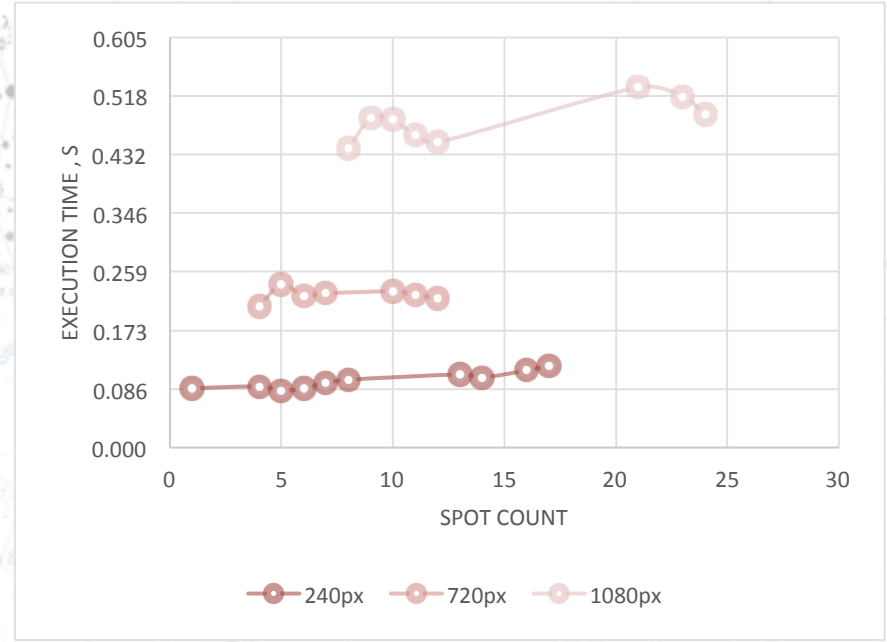
Cores 4 x Krait300
Clock up to 1.9 GHz

Second round of tests

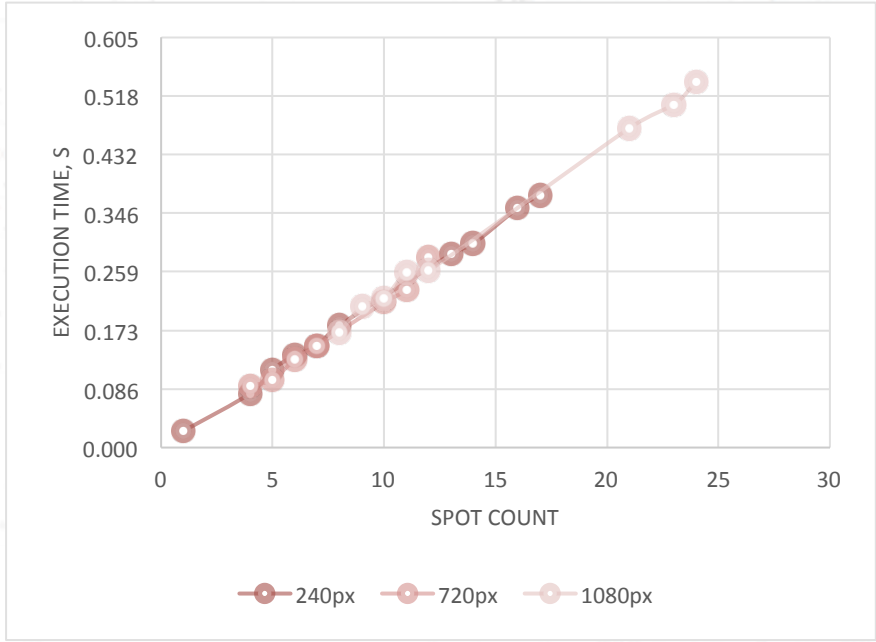


Influence of pixel and spot count

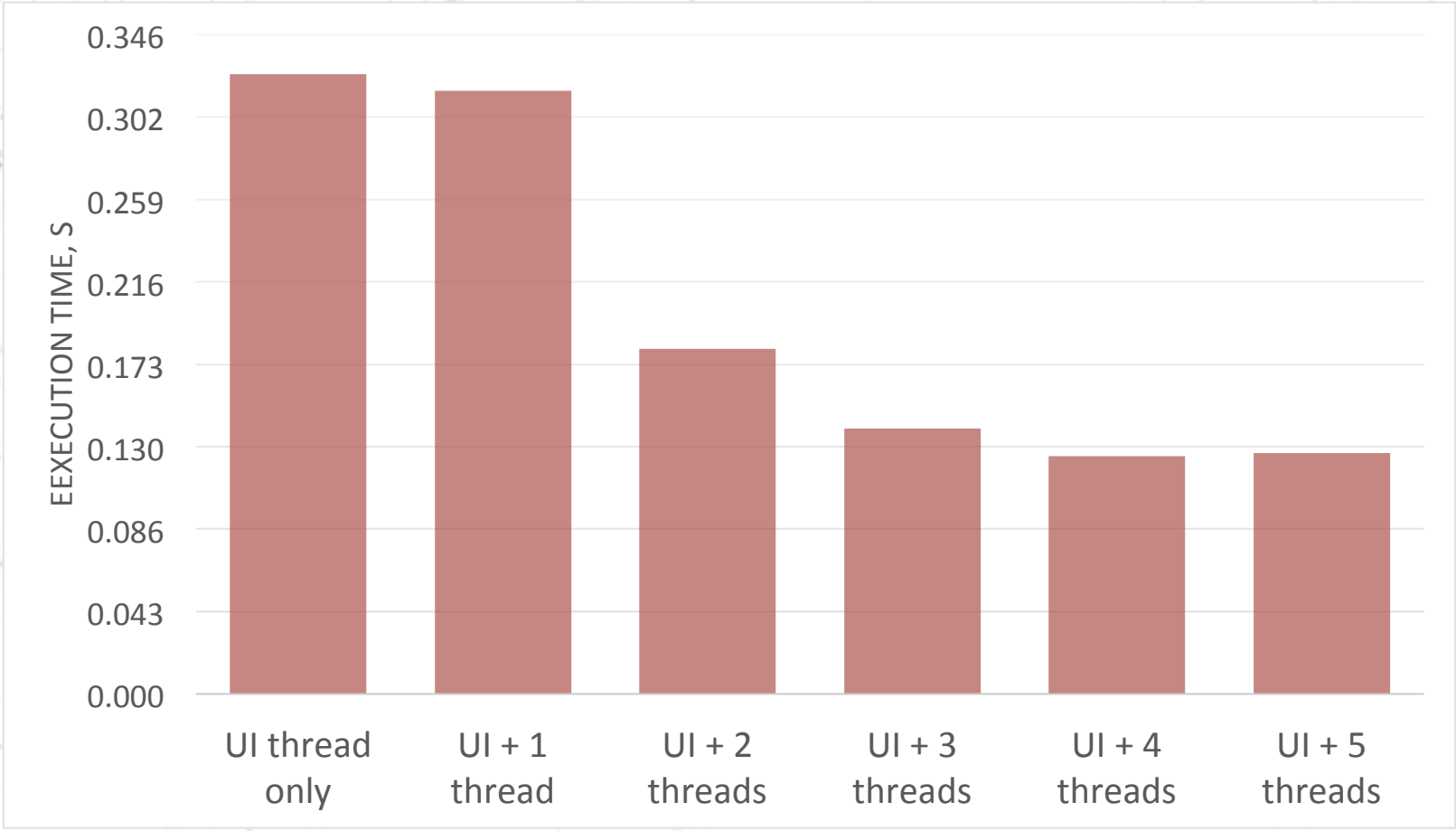
Extract step



Match step



Multi-threaded implementation



Conclusions

- ✔ Star tracker algorithm may be ported to an Android smartphone with a camera
- ✖ Smartphone-based ST has limited capabilities when used with real night sky
- ✔ Smartphone-based star tracker could be used in hardware-in-the-loop set up with sky simulation
- ⓘ Hardware solutions used in modern smartphones may give a good example of hardware architecture

Future work

Future work:

- star tracker validation (paper)
- star tracker algorithm (paper)
- tests with R3a ADCS (hardware-in-the-loop)
- special cases of hardware architecture

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