Startracking for Small Satellites: Efficient Star Identification Using a Neural Network

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Content

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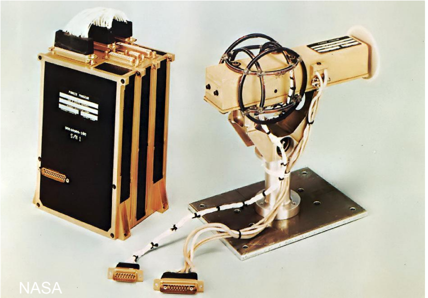
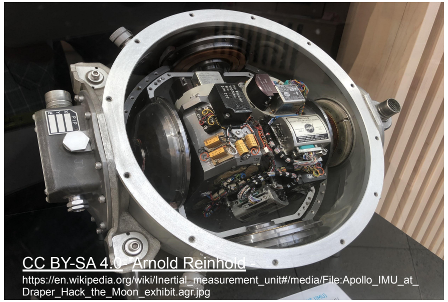
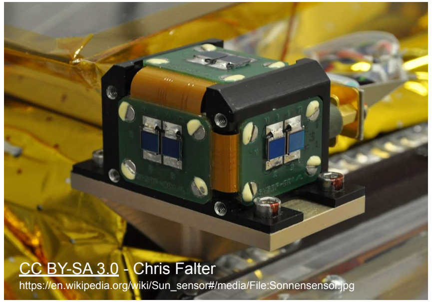
Study motivation

- High accuracy, drift-less attitude determination can not be provided on interplanetary missions by most attitude sensors







Study motivation

Jena-Optronik - https://directory.eoportal.org/web/eoportal/satellite-missions/s/smallgeo, accessed 8/4/2020

Study motivation

Comparison of accuracy of attitude determination sensors

	Reference frame	Attitude measurement accuracy
Earth sensor	Horizon	6′
Sun sensor	Sun	1′
Magnetometer	Geomagnetism	30′
Star sensor	Star	1″

Reprinted from: Zhang, G. J. (2011). Star identification. *National Defense Industry Press, Beijing*.

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Study motivation

Recent advancements in Lost-in-Space star identification algorithms

Author	Year	Feat. Ex.	S/N Environment	Type	Search	Validation
Juang et al.	2003	Pattern	High	Singular Value	$O(n)$	N/A
Silani and Lovera	2006	Hybrid	Medium	Polestar	$O(bn)$	$O(bk^2)$
Na et al.	2008	Pattern	High	Grid	$O(bn)$	N/A
Zhang et al.	2008	Pattern	High	Polestar	$O(fn)$	$O(k)$
Wei et al.	2009	Pattern	Medium	Log Polar Transform	$O(n)$	N/A
Quan and Fang	2010	Pattern	Very high	Adaptive Ant Colony	$O(log(n))$	N/A
Yoon et al.	2011	Pattern	High	Image Based	$O(n)$	N/A
Delabie et al.	2013	Pattern	High	Image Based	$O(n)$	N/A
Li et al.	2014	Subgraph	Low	Polestar	$O(b(\Delta mn)^2)$	$O(k^2)$
Aghaei and Moghaddam	2016	Pattern	Medium	Grid	$O(\alpha n)$	N/A
Schiattarella et al.	2017	Subgraph	Very low	Polestar	$O(k)$	$O(bk)$
Wei et al.	2019	Hybrid	Very low	Polestar	$O(n)$	$O(nk)$
Xu et al.	2019	Pattern	High	Deep Learning	$O(1)$	N/A
Wei et al.	2019	Pattern	High	Singular Value	$O(log(n))$	$O(k^2)$

Reprinted from: Rijlaarsdam, D.; Yous, H.; Byrne, J.; Oddenino, D.; Furano, G.; Moloney, D. A Survey of Lost-in-Space Star Identification Algorithms since 2009. *Sensors* **2020**, *20*, 2579.

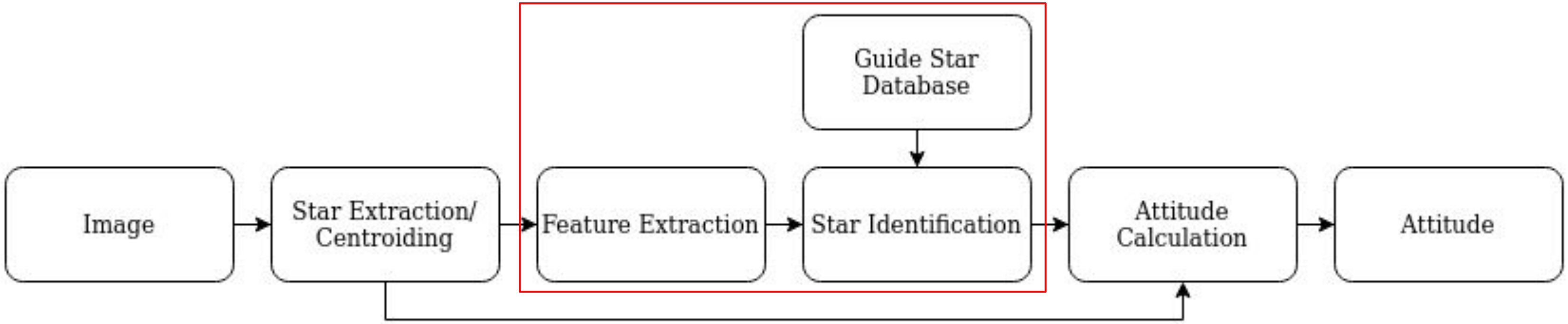
Objective

To design a robust deep learning star identification algorithm

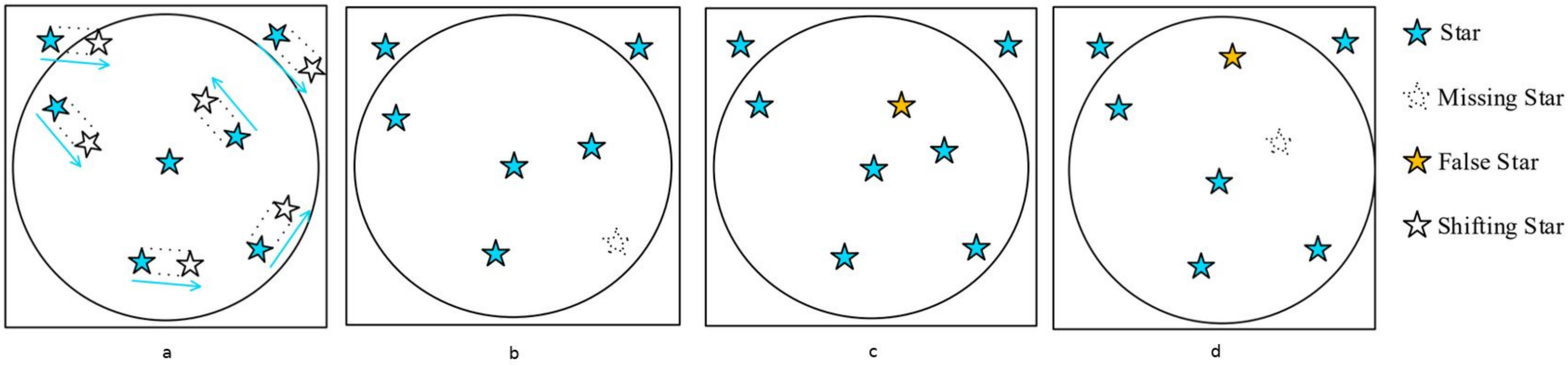
Methodology

- Analyse current state-of-the-art of star identification algorithms
- Design a compatible feature extraction method
- Design a minimalistic neural network architecture
- Implement and validate model

Methodology



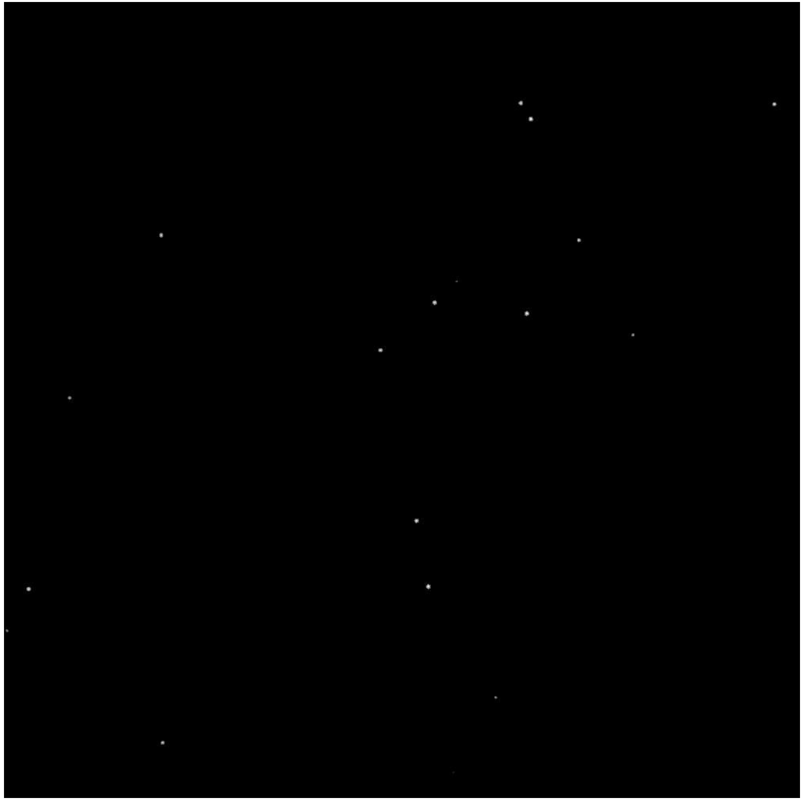
Application Environment



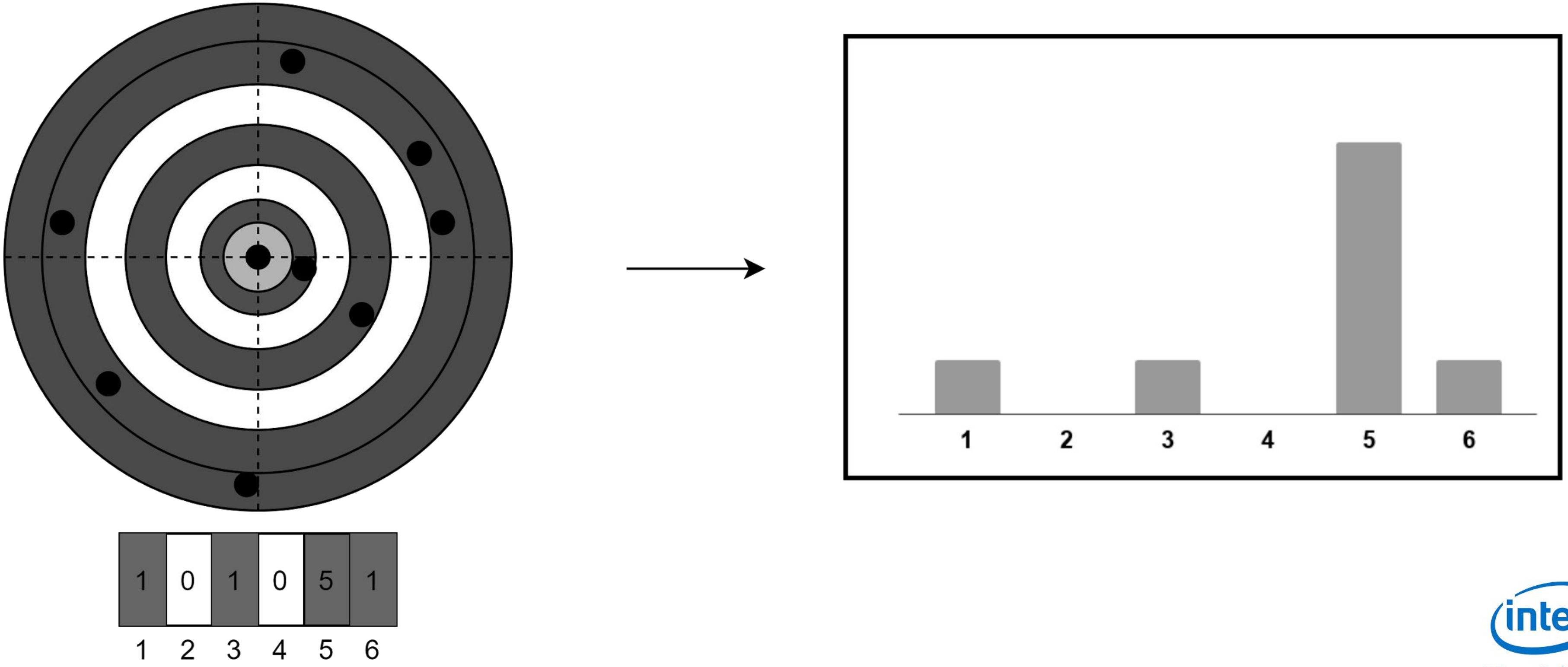
Adapted from: L. Xu, J. Jiang and L. Liu, "RPNet: A Representation Learning-Based Star Identification Algorithm," in IEEE Access, vol. 7, pp. 92193-92202, 2019.

Application Environment

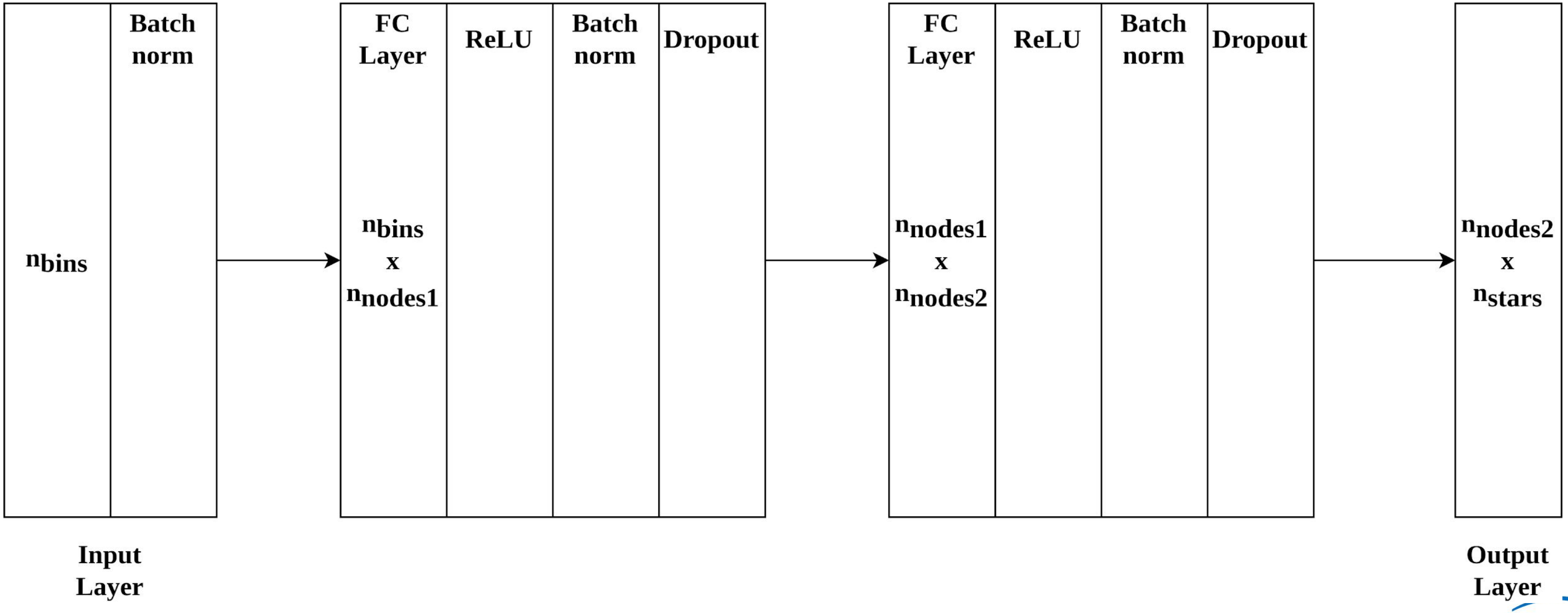
- Extremely sparse input
- Rotationally variant
- Noisy environment



Design - Novel Feature Extraction Method



Design - Network Architecture



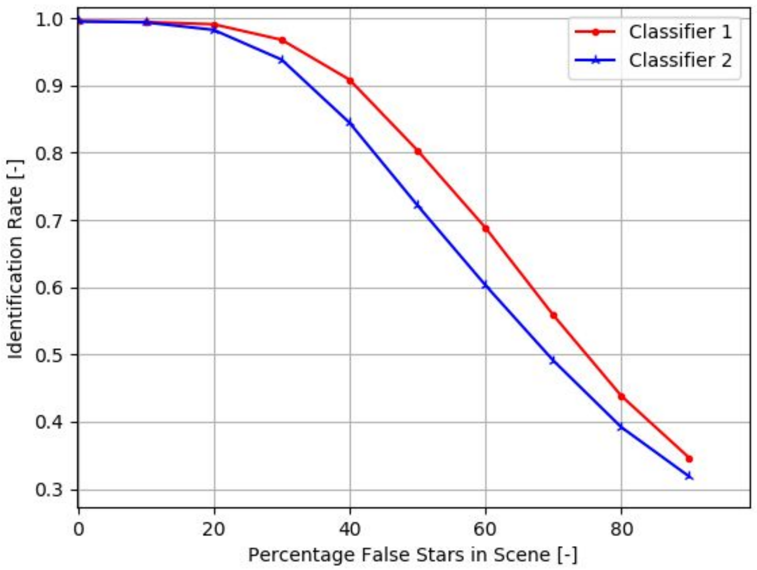
Design

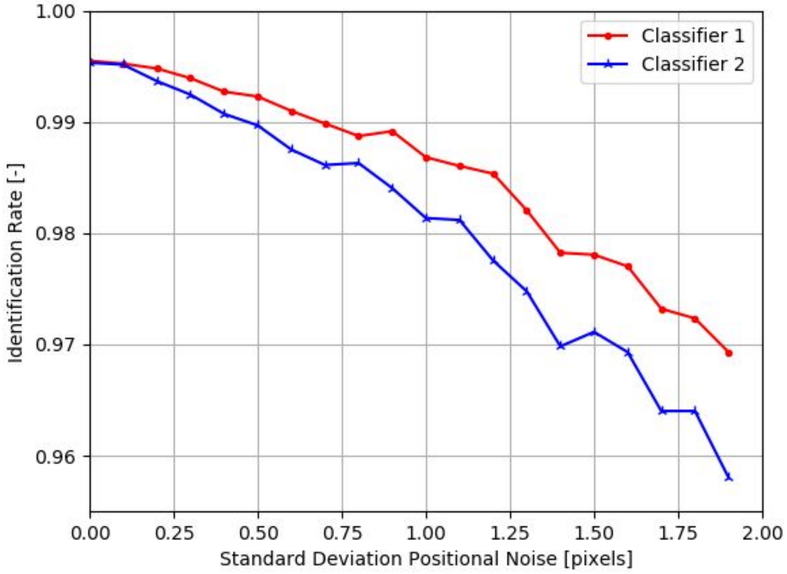
- Rotational invariant, robust feature extraction by histogram of distances to pole star
- Simple, flexible and lightweight neural network design

Results - Experimental Setup

- Star catalog and sensor model provide artificial scenes with guide star in the center
- Different levels of noise have been added in order to show underlying robustness

Results





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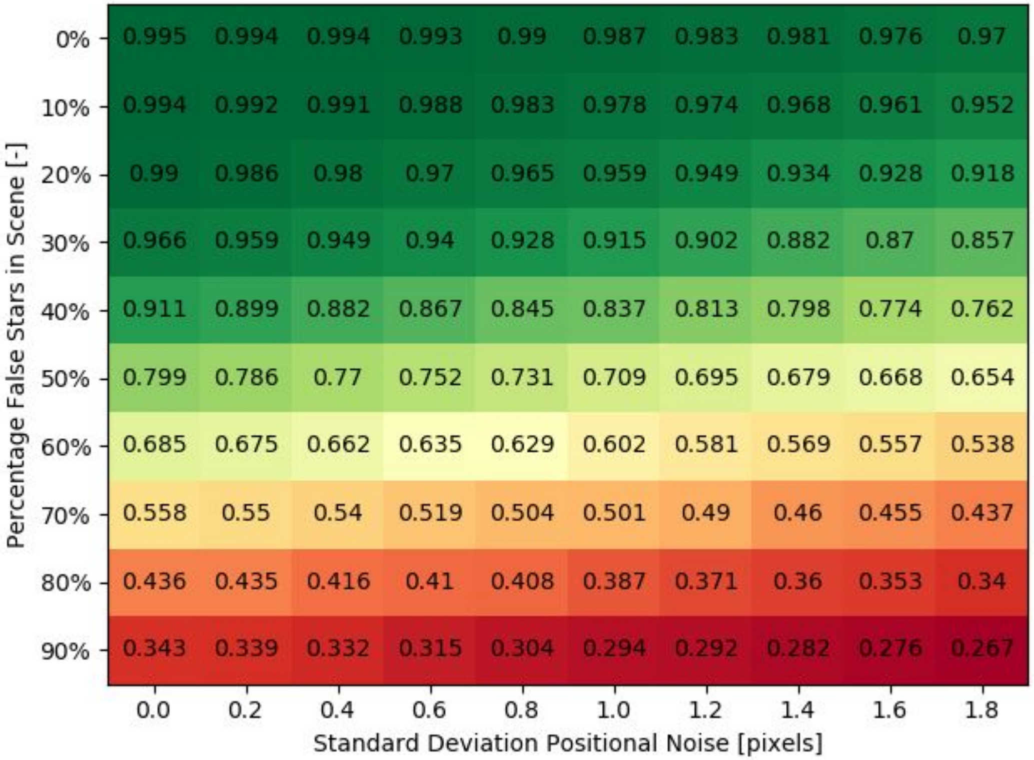
Results - Identification rate in 100 application environments



Future work

- Include verification step in end-to-end attitude determination algorithm
- Expand training data and extend network size analysis
- Optimise binning features for end-to-end attitude determination

Conclusion

- The presented algorithm provides high accuracy, lightweight attitude determination in interplanetary conditions
- Underlying robustness against noise is high
- Future optimisations can improve end-to-end performance