Improving iterative phase retrieval using neural networks

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Phase retrieval - background

u...object of interest

v...exit wave

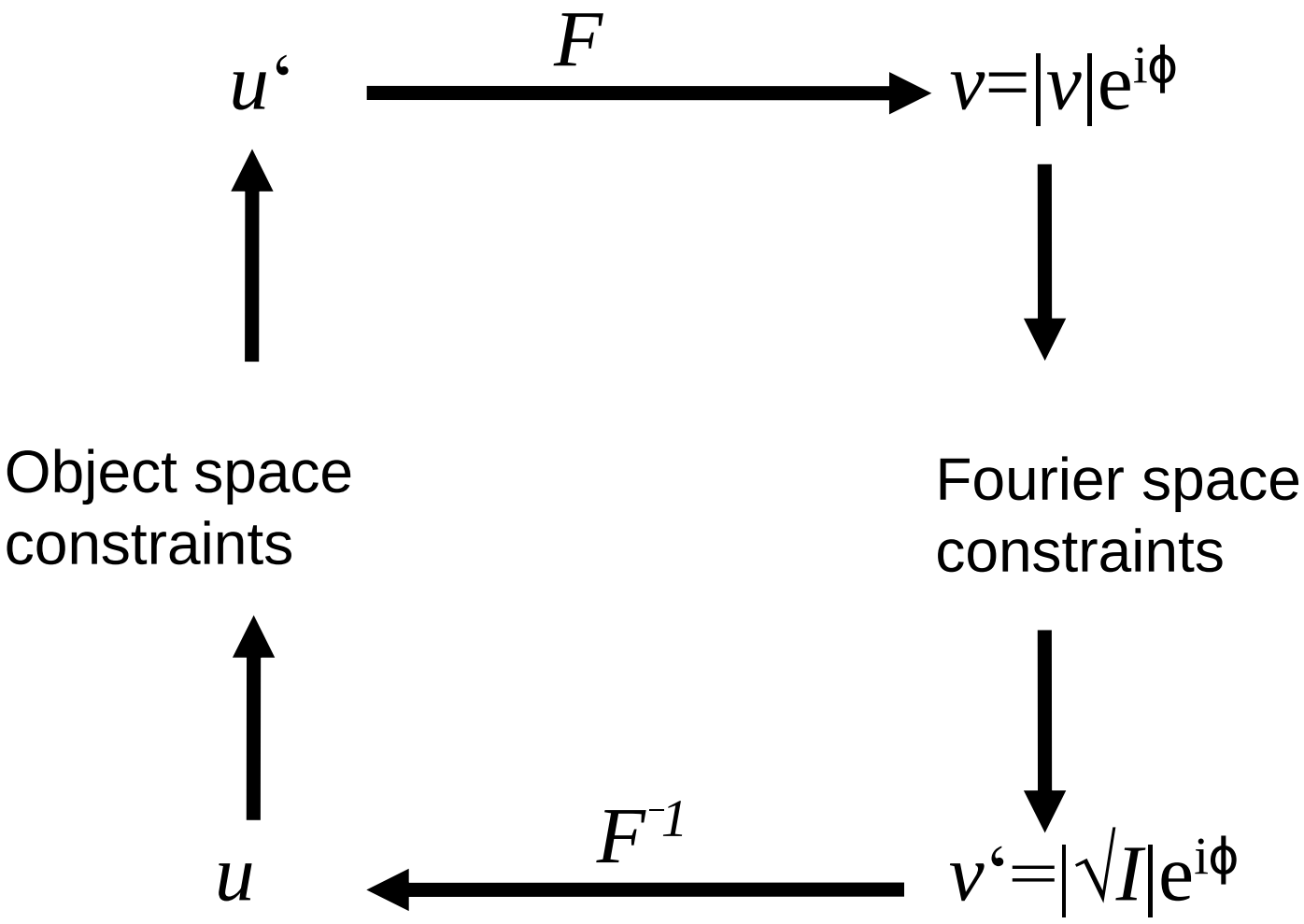
I...detected intensity on detector

Φ...phase which is not detected

$$I \sim |v|^2 = |\mathcal{F}(u)|^2$$

$$v(q) = |v(q)|e^{i\phi q}$$

Phase retrieval – iterative reconstruction



Phase retrieval – iterative reconstruction

Methods:

- Error reduction [Gerchberg, Saxton, 1972]
- Hyprid-input-output [Fienup, 1982]
- Extentions, e.g. Relaxed Averaged Alternating Reflections [Luke 2005]:

$$u_{i+1}^{RAAR} = u_i^M D + (\beta u_i + (1 - 2\beta) u_i^M)\overline{D}$$

where u_i^M is calculated from u_{i-1} being projected to M:

$$M = \{u \text{ with } |\mathcal{F}(u)|^2 = I\}$$

Drawbacks:

- Not robust, e.g. for noisy data
- Empirical optimization
- Not working for 1D data without further constraints

Phase retrieval – how to measure reconstruction quality?

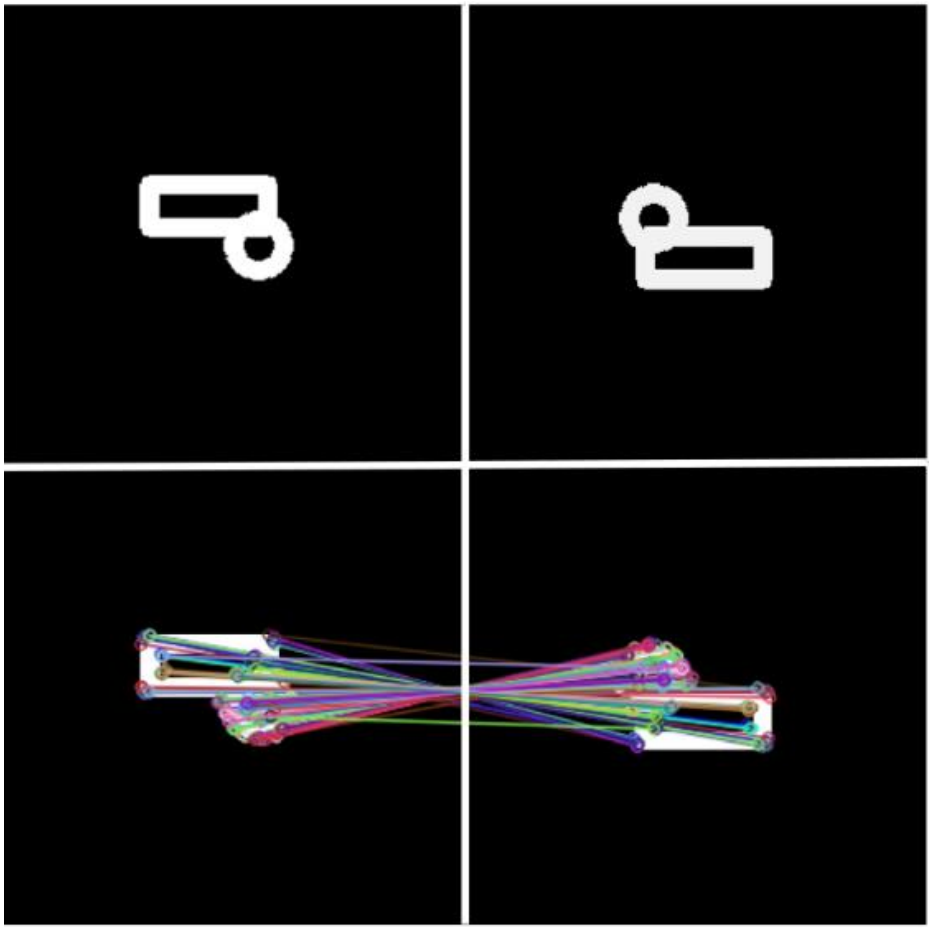
Characteristic solutions (Bates `82) are also valid, i.e. translations and phase shifts

⇒ Need for translation-invariant quality measure

⇒ ORB ratio based on „feature“ comparison

⇒ From Computer Vision

⇒ Applied in Clemens Reinhardt‘s master thesis



Phase retrieval – how to measure good reconstruction?

Characteristic solutions (Bates `82) are also valid, i.e. translations and phase shifts

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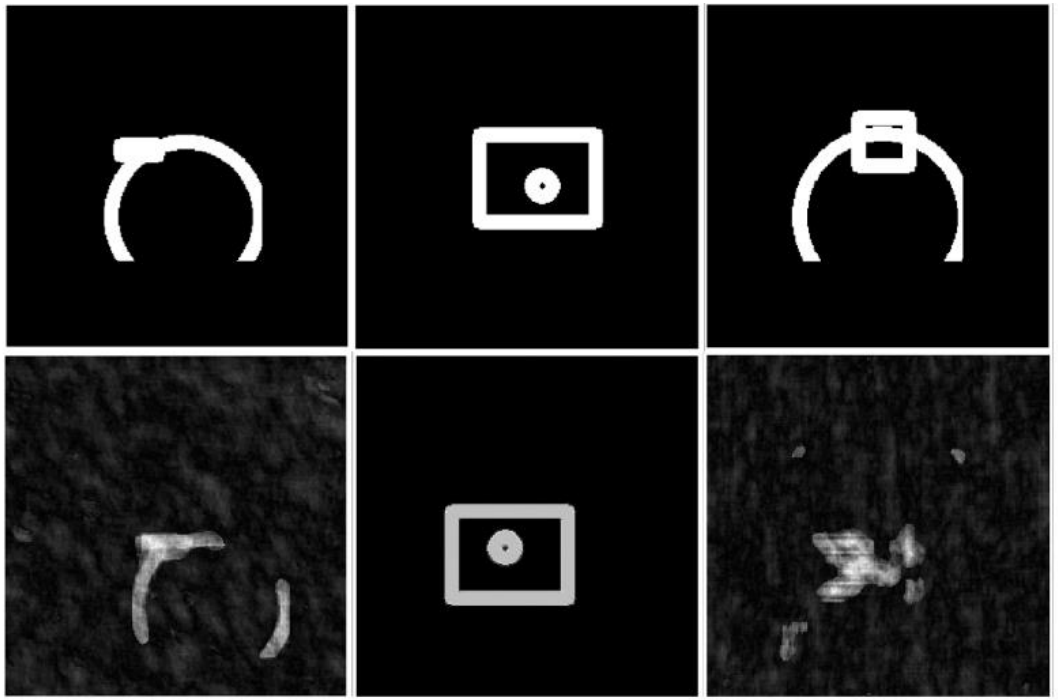
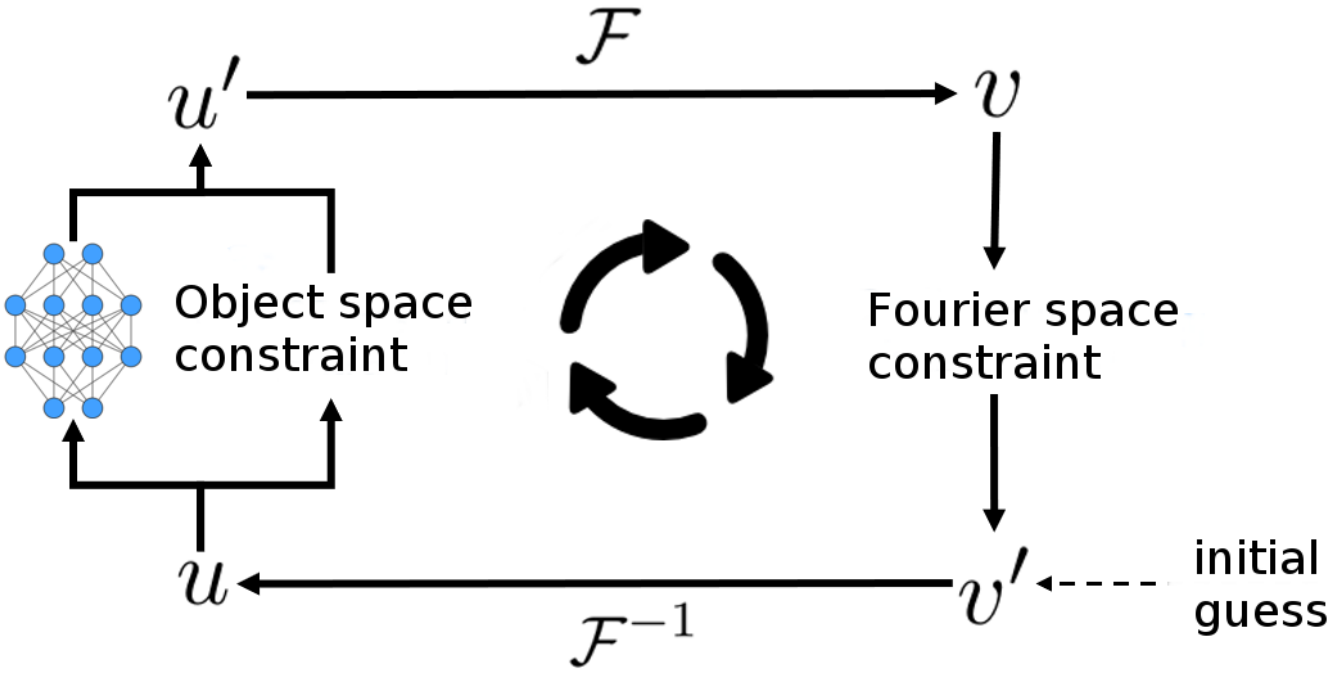


0.89 0.96 0.38

Phase retrieval – the ML approach

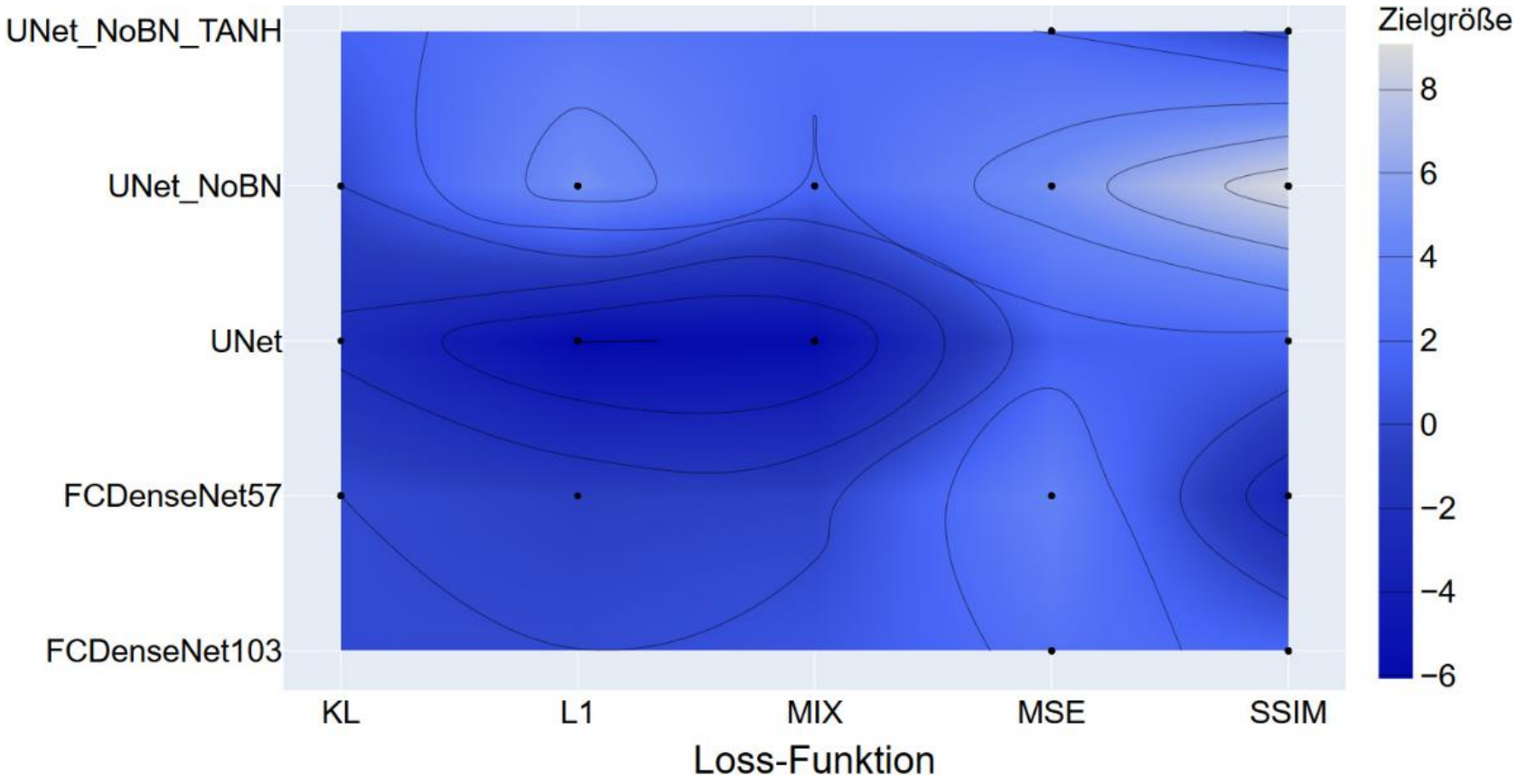


$$u_{i+1} = \alpha u_{i+1}^{RAAR} + (1-\alpha) u_{i+1}^{NN}$$

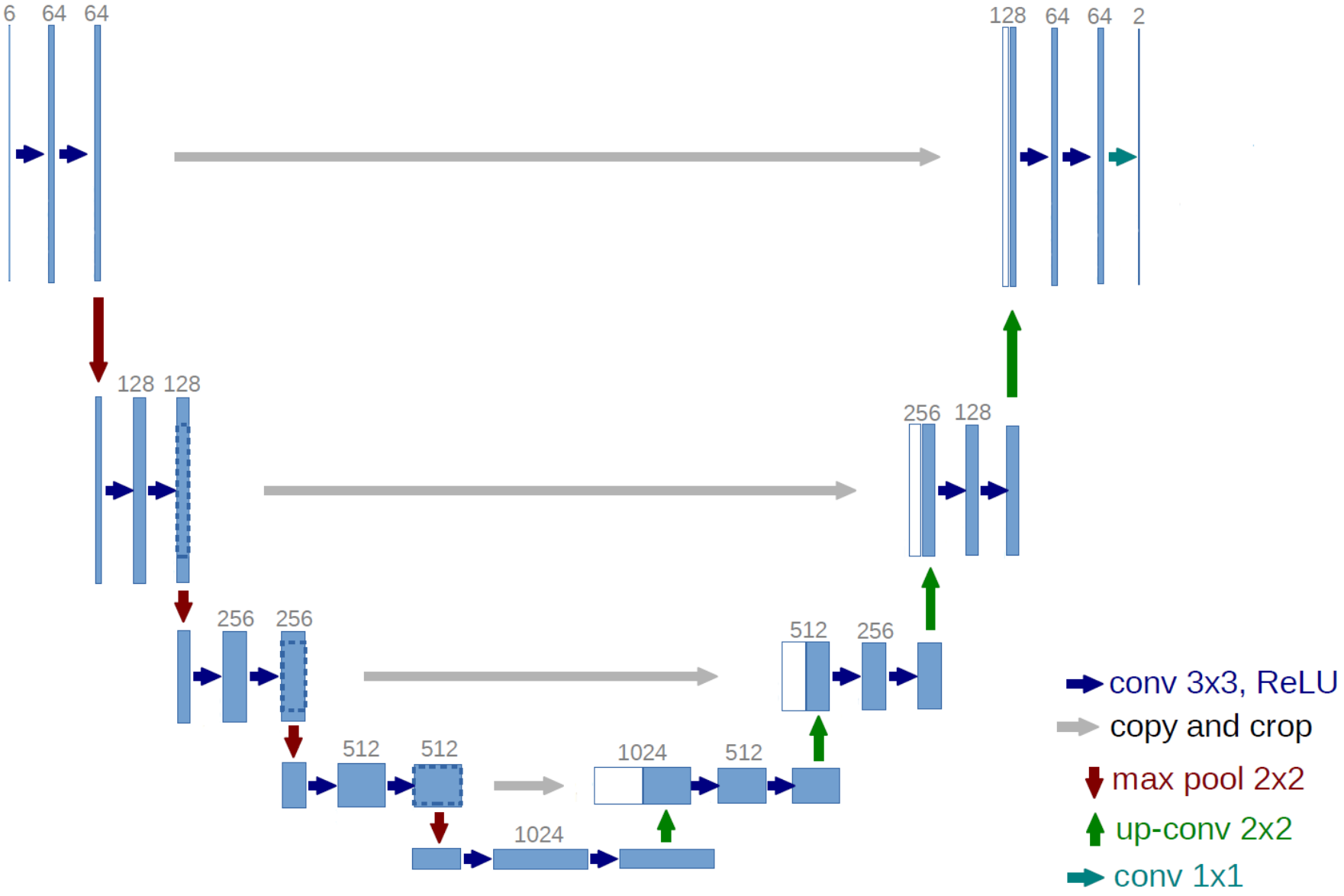
The ML approach

How to find a suitable neural network?

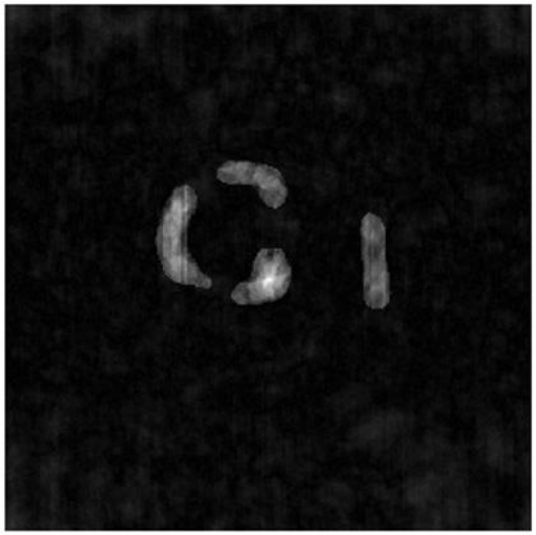
⇒ Optimization strategy for architecture and parameters using the framework OPTUNA



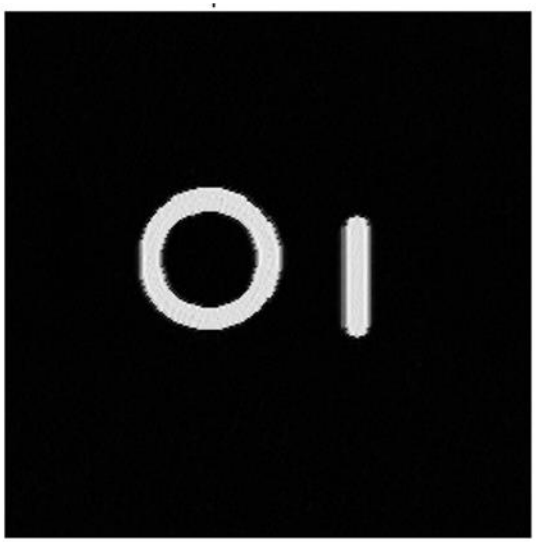
The ML approach – the winning network



The ML approach - results



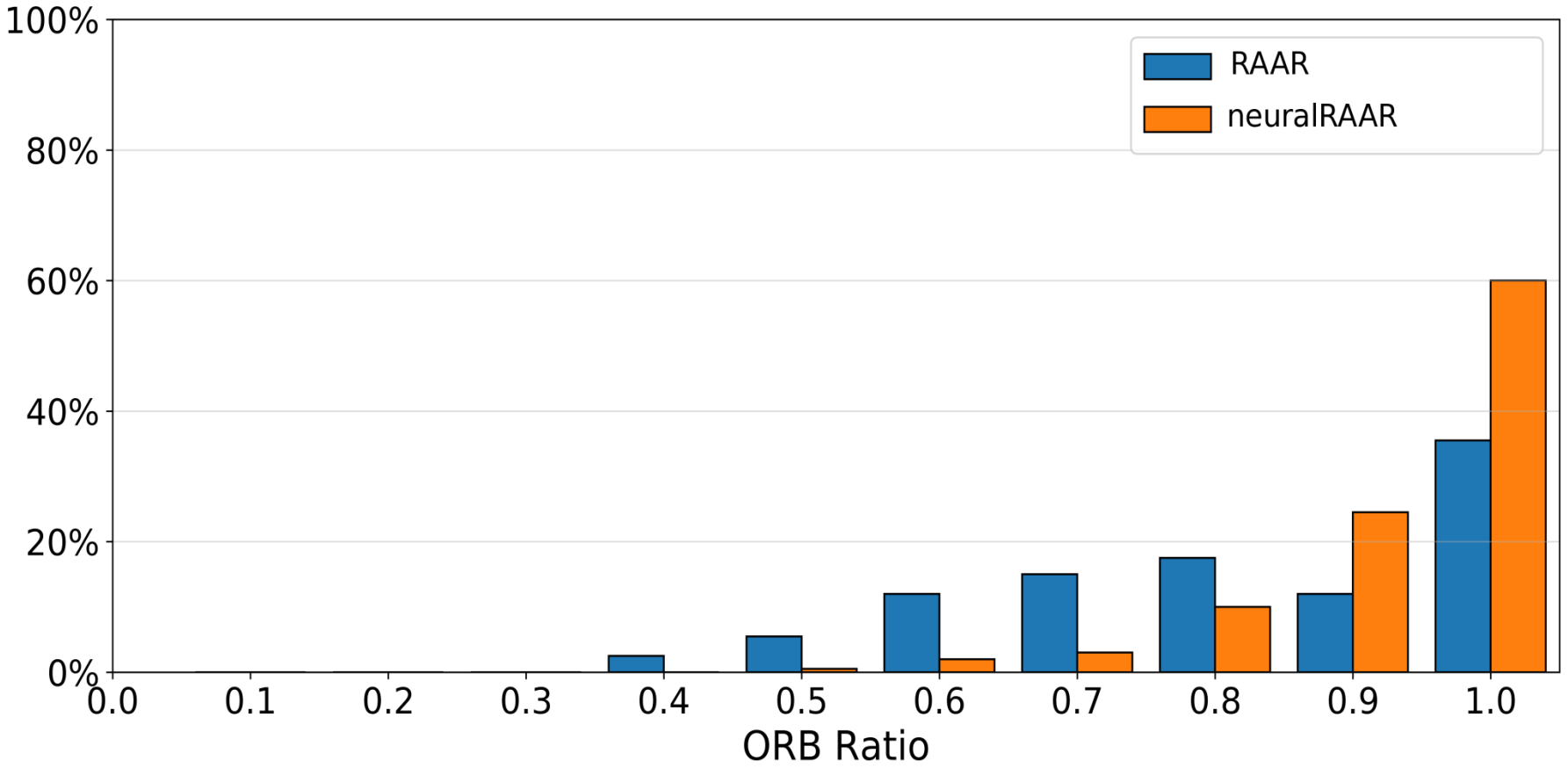
RAAR



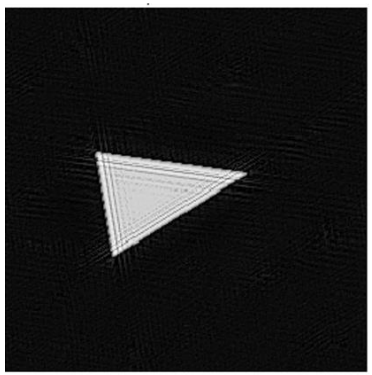
neuralRAAR

ground truth

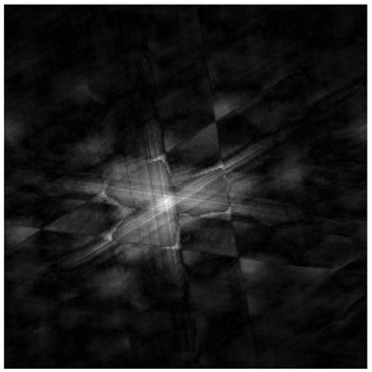
The ML approach - results



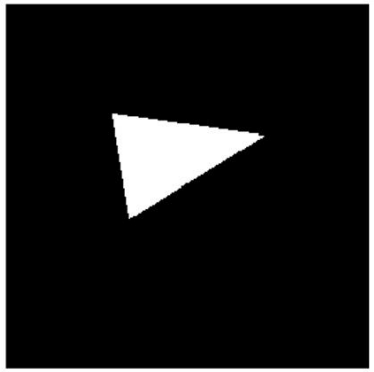
The ML approach - generalization



neuralRAAR



RAAR



ground truth