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Separability by Design: Decoupling Classification and Localization Quality in Anchor-Free Object Detection

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Abstract

Object detection research validates architectural decisions almost exclusively through mean average precision (mAP), a metric that certifies performance but conceals mechanism. We argue that principled improvement requires a detector whose classification and localization pathways are disentangled and therefore individually diagnosable. Starting from the convolutional process itself, we show that depth trades positional capacity for featural dimensionality at fixed rates set by the stage schedule, so a detection head reading both targets from one point accepts whatever proportion its depth supplies. From this decomposition we derive separability by design: classification and localization quality placed in architecturally distinct, separately supervised pathways, with an objectness route admitting localization evidence into the semantic score. Three falsifiable predictions follow, tested across eight configurations crossing head structure, box geometry and gradient coupling. All are supported. A quality field read where positional capacity survives raises its rank correlation with realized IoU from 0.051 to 0.484; two levels recover the localizability of a five-level pyramid, at 0.943 against 0.950 oracle recall; and the convolutional head commits its class field in the forward pass, reducing candidate entropy from 3.66 to 2.22 bits and uncorroborated rare survivors from 3.2% to 0.9% across 5000 COCO val2017 images. The prediction concerning the objectness route holds conditionally: the gate lifts the class score only where the class head can read the spatial neighborhood the objectness cue occupies, which requires both a convolutional head and a cue-preserving geometry. The contribution is a framework and a diagnostic method for mechanistic detector analysis that enables systematic architectural design, not a leaderboard result. © 2013 IEEE.

Author keywords

anchor-free detection; error diagnosis; feature entanglement; localization quality; model interpretability; Object detection

Indexed keywords

Engineering controlled terms

Architectural design; Computer aided diagnosis; Convolution; Error analysis; Error detection; Feature extraction; Object recognition; Semantics

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Abstract