Neural Algebra of Classifiers
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1 - INTRODUCTION & MOTIVATION

● Which one is the albatross?
Albatrosses are birds with hooked beak and large wingspan. (hooked beak AND large wingspan)
● Which ones is the frigatebird?
Frigatebirds seem black albatrosses with white or red pouch. (albatross AND (white pouch OR red pouch))

“The human recognition system is fundamentally compositional, so the unseen complex concepts are recognized from the composition of simple visual primitives according to well-defined rules.”

2 - GOALS & CONTRIBUTIONS

We aim to develop a learning framework to synthesize classifiers for arbitrary compositions of visual primitives.

Contributions:
● Learning framework for composition of classifiers.
● Compositional neural network based model which minimizes the classification error of a subset of visual compositions and generalizes for unseen compositions.
● The proposed framework can recognize unseen classes, subclasses and specific instances of objects without additional annotation effort.

3 - PROBLEM FORMULATION

We propose an algebra of visual primitives:

● Visual primitives (p): known simple visual concepts, e.g., hooked beak (hb) and large wingspan (lw).
● Composition rules: (∧, AND) conjunction, (∨, OR) disjunction, and (¬, NOT) negation.
● Expressions (e): visual concepts expressed as multiple compositions of primitives and composition rules, e.g., albatrosses = hb AND lw.

We model the function \( f_\Theta(e) \) as a set of composition functions by decomposing expressions in simple terms and evaluating them recursively.

\[
g^\wedge (w_a, w_b) = \text{Neural Network}(w_a, w_b)
\]

\[
g^\vee (w_a, w_b) = g^\wedge (g^\wedge (w_a), g^\wedge (w_b))
\]

● These composition functions are autoregressive models.
● The negation is defined analytically.
● The disjunction is defined according to the De Morgan's Laws.
● The conjunction is a multilayer perceptron (MLP).

4 - LEARNING & INFERENCE

We propose to learn a parameterized function \( (w_e = f_\Theta(e)) \) that maps the space of expressions to the space of binary classifiers using a relative small subset of training expressions and relying on the classifier similarity to generalize for unknown expressions.

5 - COMPOSITION FUNCTIONS

6 - RESULTS

Simple Binary Expressions:

Complex Unknown Expressions: \((p_1 \lor q_1) \land (p_2 \lor q_2) \land \ldots \land (p_c \lor q_c)\)

Qualitative Evaluation