From Mechanistic to Compositional Interpretability

AUTOMATING INTERPRETABILITY AS A CONSTRAINED OPTIMISATION PROBLEM...

Requires a measurable blueprint for discovering and evaluating mechanistic explanations.

Aim

Mechanistic interpretability aims to reverse-engineer neural computation into human-understandable parts in three steps: decompose, describe, validate *(Sharkey 2025)*.

Gap

Without a formal framework, explanations can't be objectively verified, compared or composed. They can be locally valid yet globally inconsistent *(Joshi 2026)*.

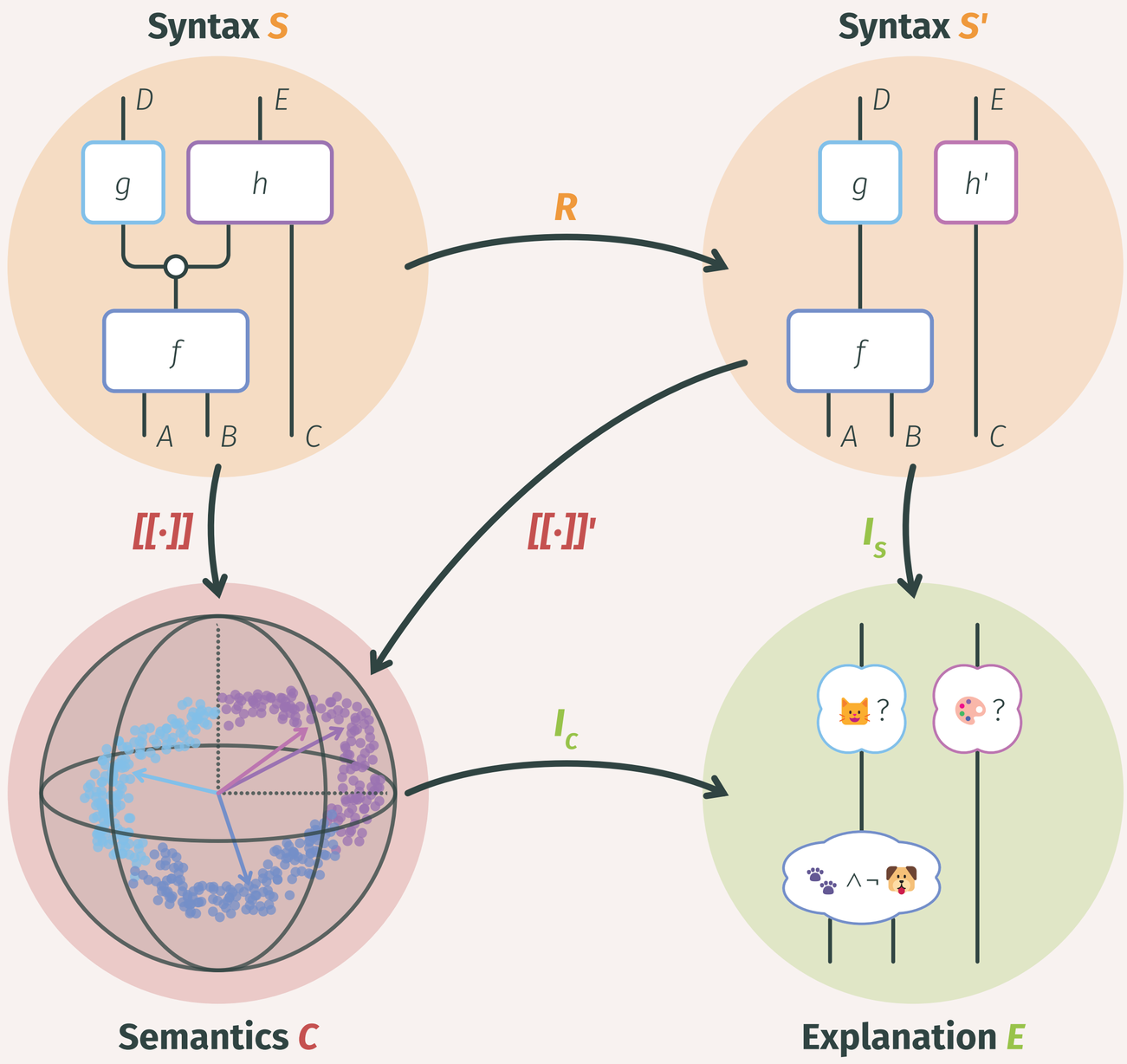
Framework

Compositional interpretability is based on two principles:

- Compositionality for grounding (category theory)
- MDL for selection (information theory)

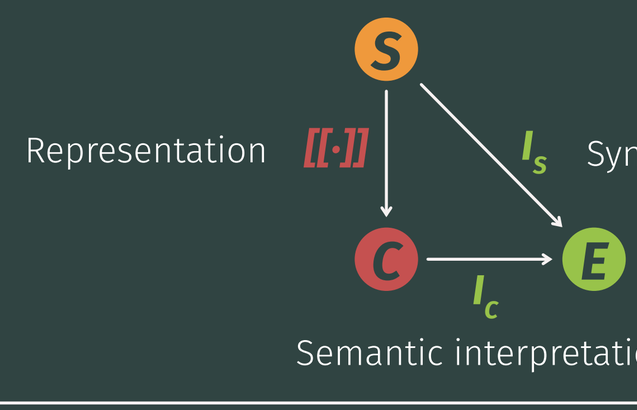
Payoff

- Formal criteria for explanation selection
- Spectrum of techniques generalising current methods
- Interpretability as a rate-distortion problem



1. WHAT ARE COMPOSITIONAL INTERPRETATIONS?

Model decompositions have *syntax* and *semantics*. Mechanistic explanations should be grounded in both.



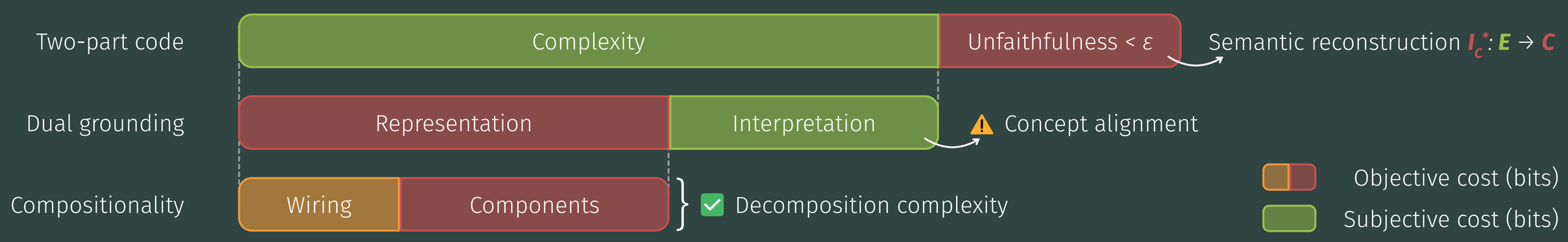
Syntax ***S*** E.g. string diagrams, feature circuits, PyTorch modules

Semantics ***C*** E.g. differentiable functions, distributions, relations

Explanation ***E*** E.g. natural language, causal models, pseudocode

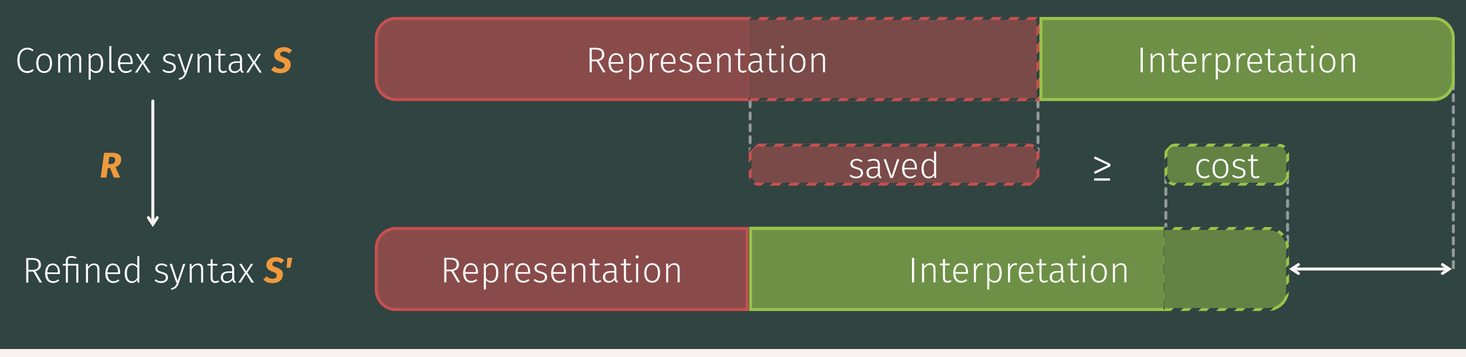
2. WHAT MAKES EXPLANATIONS GOOD?

Interpretation is communication. Good explanations have m*inimal description length*. We give a measurable upper bound.



3. HOW DO WE FIND BETTER EXPLANATIONS?

Compressive refinement simplifies representations. Under the *parsimony criterion*, simpler means more interpretable.

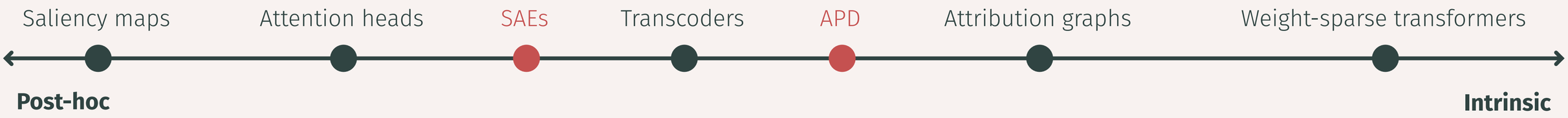


Comonotonic coding suffices.

If the coding distribution encodes *explanatory optimism (Ayonrinde 2025)*, both complexities fall together. More realistic codes give better refinements.

EVERY MECHANISTIC METHOD IS A COMPRESSIVE REFINEMENT...

They can be compared qualitatively, their explanations selected quantitatively, and judged by the parsimony criterion.



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