# TARTAN: A Framework for Trajectory-Aware Recursive Tiling with Annotated Noise

Anonymous

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**Abstract**

TARTAN (Trajectory-Aware Recursive Tiling with Annotated Noise) is a novel framework for encoding spatial, physical, and semantic metadata into the visual substrate of dynamic scenes. By integrating recursive tiling, Gaussian aura beacons, pixel-stretched worldline encoding, annotated noise fields, and holographic tartan overlays, TARTAN transforms each frame into a self-contained ledger of a scene's evolution. Unlike conventional generative models, which rely on brute-force computation and lack cognitive grounding, TARTAN embeds causal and intentional truths, enabling physics-aware reconstruction and semantic transparency. Applications span computer vision, sustainable design, and visual storytelling, offering a robust antidote to epistemic opacity in digital systems.

## 1 Introduction

Modern generative models, such as transformer-based large language models (LLMs) and IBM Watson, achieve competence through computational scale but lack alignment with biological cognition. Their reliance on arbitrary architectures—handcrafted scorers in Watson, multi-head attention in transformers—produces epistemically brittle outputs that fail to capture the embodied, predictive nature of human reasoning. TARTAN addresses this gap by encoding a scene's spatial, temporal, and intentional dynamics into its pixel space, creating frames that are simultaneously visual artifacts and reconstructable ledgers.

## 2 Critique of Brute-Force Architectures

### 2.1 Limitations of Watson and Transformers

IBM Watson employs a directed acyclic graph (DAG) of over 1,000 handcrafted scorers, while transformers leverage dense matrix operations across billions of parameters. Neither resembles the sparse, energy-efficient networks of biological cognition, which integrate astrocytes and neurons for predictive processing [2, 4]. Key limitations include:

- **Architectural Arbitrariness**: Watson's scorers and transformers' attention mechanisms are engineering conveniences, not neurobiological principles. No organism uses backpropagation or softmax attention [7].
- **Epistemic Mismatch**: Both systems lack sensorimotor grounding, relying on disembodied token processing rather than embodied feedback loops [5, 8].
- **Functional Myopia**: Watson aligns tokens via heuristic scoring, while transformers minimize cross-entropy, leading to hallucinations and brittleness [1, 6].
- **Cognitive Inefficiency**: Biological systems compress knowledge via predictive coding, while Watson and transformers enumerate candidates or parameters [3, 8].

## 2.2 Toward Cognitively Natural Systems

Future AI must embrace active inference, predictive coding, and symbol grounding to align with evolutionary principles [3, 5, 7]. TARTAN embodies these ideals by encoding causal substrates—physics, intent, and semantics—into visual frames, offering a transparent, biologically plausible alternative.

# 3 Core Principles

TARTAN posits that every actor and event in a scene should be represented as a field-emitting entity, with its history, behavior, and trajectory embedded in the visual substrate. This ensures that each frame is a multidimensional record, capable of being read visually, verified steganographically, reconstructed algorithmically, and interpreted semantically.

# 4 Technical Framework

## 4.1 Recursive Tiling

Scenes are partitioned into hierarchical tiles (e.g., quadtrees or concentric bands), each encoding layered attributes such as color, texture, motion vectors, and semantic labels. This multi-resolution structure prioritizes detail based on dynamic complexity or narrative significance.

## 4.2 Gaussian Aura Beacons

Each actor emits a Gaussian field, or aura-beacon, radiating attributes including:

- **Temperature**: Thermodynamic state or emotional tone.
- **Density**: Material concentration or attention weight.

- **Velocity Vector**: Speed and direction.
- **Trajectory**: Predicted path or intent.

These fields overlap and interfere, forming a soft signal network that captures the scene's physical-psychological atmosphere.

### 4.3 Pixel Stretching and Worldline Encoding

Motion is encoded by stretching pixels along an actor's worldline, embedding:

- **Direction**: Path taken.
- **Length**: Speed.
- **Curvature**: Acceleration or turning.
- **Color/Opacity**: State changes (e.g., fading heat).

This transforms each frame into a 4D imprint, warping time into the spatial domain.

### 4.4 Annotated Noise Fields

Structured noise is injected as a semantic carrier wave, encoding:

- Hidden metadata (via steganography).
- Scene class priors.
- Temporal uncertainty.
- Narrative role cues (e.g., protagonist, obstacle).

This ensures that every pixel is probabilistically expressive.

### 4.5 Holographic Tartan Overlay

A grid-based tartan pattern, either visible or steganographic, embeds compressed representations of scene layout, object relationships, material origins, and symbolic metadata. Each stripe or square may contain a recursive snapshot of the whole, enabling holographic reconstruction.

## 5 Generative Reconstruction

Diffusion models trained on TARTAN-encoded data reconstruct scenes with physics-aware, intention-consistent outputs. By leveraging embedded worldlines and aura fields, these models denoise truth rather than hallucinate textures, enabling applications in video synthesis, forensic analysis, and interactive storytelling.

## 6 Applications

- **Computer Vision**: Enhanced scene understanding for autonomous systems.
- **Sustainable Design**: Transparent material provenance via tartan-encoded packaging.
- **Visual Storytelling**: Dynamic overlays for narrative-driven cinema or gaming.

## 7 Discussion

TARTAN's commitment to semantic transparency challenges the epistemic opacity of brute-force systems like Watson and transformers. By encoding causal substrates, it offers a framework for verifiable digital artifacts. Challenges include computational overhead and the need for standardized decoding protocols, which future work will address.

## 8 Conclusion

TARTAN reimagines visual encoding as a tapestry of truth, where pixels are threads, auras are dyes, and tartan grids are weaves of meaning. By aligning with biologically plausible principles—predictive coding, symbol grounding, and active inference—it transcends the limitations of current AI, paving the way for transparent, accountable digital systems.

## References

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