Behavioral Alignment Framework — Theory & Design Note

# 1. Motivation & Pivot

Earlier T0.4 approaches attempted direct kinematic mapping between humans (bipedal) and dogs (quadrupedal). This failed review due to mismatched topology and lack of provable invariants. The Behavioral Alignment Framework replaces kinematic mapping with intent→behavior alignment: map coarse human intents into species-native dog behaviors with explicit uncertainty.

# 2. Core Concept

We define a Behavioral Intent Encoder for humans, a Quadruped Behavior Library with priors, an Intent→Behavior Matcher, and an Uncertainty Head. Together these provide an interpretable, uncertainty-aware mapping suitable for synchrony analysis.

# 3. Modules

• Behavioral Intent Encoder: CNN/MLP on IMU features → intent distribution (rest, steady locomotion, rapid locomotion, transition).

• Quadruped Behavior Library: species-native behaviors with duty factors, phase patterns, spectral templates, duration priors.

• Intent→Behavior Matcher: hybrid rule+ML mapping (intent distribution × library compatibility).

• Uncertainty Head: combines entropy, morphology gap, temporal mismatch, constraint slack into a calibrated uncertainty score.

# 4. Mathematical Formulation

Let I be the intent distribution from human IMUs, B the quadruped behavior distribution from the library. Matcher computes: p(b|I) ∝ p(I) × exp(−d(z\_I, z\_B)), where d is a distance in invariant space (e.g. Mahalanobis). Uncertainty U = w1\*H(I) + w2\*morph\_gap + w3\*temporal\_mismatch + w4\*constraint\_violation\_rate.

# 5. Interfaces

Input: human IMU sequences.  
Intermediate: intent distribution + features.  
Output: quadruped-compatible behavior distribution + uncertainty.  
Optional: limb sequence decoding via GNN or HSMM if required downstream.

# 6. Validation Tiers

Tier 1: Behavioral alignment — accuracy ≥70%, ECE <0.10.  
Tier 2: Species plausibility — duty factor RMSE, footfall legality, COM waveform correlation.  
Tier 3: Distributional match — Wasserstein/MMD distances, expert plausibility ratings.

# 7. Implementation Notes

- Use entropy-constrained quantization for efficiency.  
- Behavior library can be seeded with curated small datasets.  
- Calibrate uncertainty with isotonic regression.  
- Pre-train on human datasets, fine-tune with dog exemplars.

# 8. Conclusion

This pivot provides a theoretically sound, auditable, and practically implementable pathway. It emphasizes uncertainty and species-native behaviors, ensuring higher acceptance at D1 and beyond.