

# Inferring Beliefs and Control Parameters from Continuous Behavior

Inferring the computational strategies behind goal-directed behavior remains a fundamental challenge in neuroscience [1]. While inverse optimal control provides a principled framework for this task [2], existing methods often rely on restrictive optimality assumptions and computationally expensive Monte Carlo sampling [1]. We propose a novel, efficient framework that infers latent beliefs and control parameters without assuming optimality or specifying a particular cost function.

By formulating sensorimotor loops as linear-Gaussian state-space models, we derive an analytic complete-data likelihood that enables inference via a deterministic Expectation-Maximization (EM) algorithm [3]. Unlike previous approaches [1], our formalism explicitly accounts for internal noise within the agent’s computations. This inclusion is crucial, as even small internal noise is sufficient to break the “separation principle” [4] inherent in standard Linear-Quadratic-Gaussian (LQG) models, allowing for richer and more realistic control strategies.

Validation on synthetic agents shows our method recovers ground-truth parameters with less than 5% error. Applied to human tracking data [5], the algorithm produces multi-subject fits in under five minutes on a standard laptop. Our results reveal that human control gains decrease with stimulus uncertainty, departing from purely optimal predictions. This shift, combined with non-monotonic estimator gains, is best explained by a concurrent rise in sensory and internal noise as task difficulty increases. Ultimately, this framework offers a robust, efficient tool for extracting latent variables from continuous behavior, facilitating direct connections to neural activity.

## References

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