Information Saturation Theorem

I. Theorem Statement

Autonomous systems — both biological and artificial — will experience a decline in performance when information density exceeds a system-specific critical threshold.

Let:

- $D(t)$: Information density over time
- $P(t)$: System performance
- θ_i: Critical information saturation threshold

If:

$$D(t) > \theta_i \quad \Rightarrow \quad \frac{dP}{dt} < 0$$

Then the system enters a performance degradation phase, reflected by decreased symbolic coherence, accuracy, or interpretability.

II. Formal Definitions

- **Information Density** $D(t)$: Volume and entropy of data processed per unit time.
- **Performance Function** $P(t)$: Measurable output quality (accuracy, coherence).
- **Saturation Threshold** θ_i: Maximum density the system can sustain before degradation.

III. Key Mechanisms

Adaptive Filtering

Function $F(t)$ dynamically prioritizes relevant data and discards low-entropy inputs to maintain stability near θ_i.

Self-Optimization Protocols

Feedback systems modify intake and processing behavior to mitigate performance loss near saturation.

Collapse Gradient

If $D(t)$ continues to exceed θ_i, the degradation of $P(t)$ becomes nonlinear, representing a collapse in coherence.

IV. Testable Predictions

AI Systems

- Recursive inputs reduce coherence scores (e.g., BERTScore, BLEU).
- Logit entropy increases under saturation.
- Hallucination frequency rises in generative models.

Human Cognition

- EEG entropy and pupil dilation increase with information overload.
- Reaction time and symbolic reasoning accuracy decline.

V. Simulation Design

Model Setup

- **Models:** Transformers, VAEs, symbolic logic nets
- **Input:** Increasing entropy and volume data streams
- **Metrics:** Mutual Information, BERTScore, error rate, coherence

Cognitive Parallel

Human subjects under memory and attention constraints demonstrate phase-shift performance collapse.

VI. Practical Implications

- **AI Safety:** Avoid collapse through entropy-aware filters
- **UX/Design:** Regulate interface complexity to reduce overload
- **Cognition:** Model and prevent collapse in high-load environments
- **Systems Theory:** Define performance envelopes in symbolic AI