Quantum Emoji Encoder: A Qubit-Based Model of Emotional Expression and Collapse

Nilanjan Panda
Department of Energy Science and Engineering, IIT Bombay

Abstract

Human emotion rarely exists as a single definitive state; it is a quantum-like superposition of several tendencies such as sadness, joy, anger, or affection. The *Quantum Emoji Encoder* models this internal uncertainty as a quantum state, representing emotional valence and tone on the Bloch sphere and interpreting digital communication as a measurement-induced collapse. This paper presents a full derivation of the model: mapping emotional parameters to qubit angles, computing Born-rule probabilities, evaluating Shannon entropy, constructing density matrices, and analyzing temporal collapse. Theoretical and simulated results link affective computing, quantum cognition, and information theory, illustrating a novel mathematical representation of emotion.

1 Introduction

Human emotions are dynamic, uncertain, and context-dependent. Classical probability can capture mixtures of emotional states but not the interference effects that arise from overlapping intentions or tones. Quantum cognition frameworks [1,2] suggest that the probabilistic nature of decision and expression follows quantum probability rather than classical Bayes' rule.

This model treats emotion as a qubit—a two-level system that allows superposition and interference. Sending an emoji is modeled as a projective measurement collapsing the internal state into a single observable symbol. Through this analogy, we bridge quantum mechanics, psychology, and digital communication.

2 Mathematical Framework

2.1 Two-State Emotional Space

We define two orthonormal basis states:

$$|e_1\rangle = |\text{sad}\rangle, \qquad |e_2\rangle = |\text{happy}\rangle. \tag{1}$$

An individual's internal emotional state before expression is a superposition:

$$|\psi\rangle = \alpha|e_1\rangle + \beta|e_2\rangle, \quad |\alpha|^2 + |\beta|^2 = 1, \tag{2}$$

where $\alpha, \beta \in \mathbb{C}$ encode affective strength and phase coherence.

2.2 Bloch-Sphere Parameterization

The qubit can be represented as:

$$|\psi(\theta,\phi)\rangle = \cos\left(\frac{\theta}{2}\right)|e_1\rangle + e^{i\phi}\sin\left(\frac{\theta}{2}\right)|e_2\rangle. \tag{3}$$

Here $\theta \in [0,\pi]$ is the emotional *valence angle* and $\phi \in [0, 2\pi)$ is the *tone phase* (sarcasm or sincerity).

The Bloch vector is:

$$\vec{r} = \begin{pmatrix} \sin\theta\cos\phi \\ \sin\theta\sin\phi \\ \cos\theta \end{pmatrix}, \quad \|\vec{r}\| = 1. \tag{4}$$

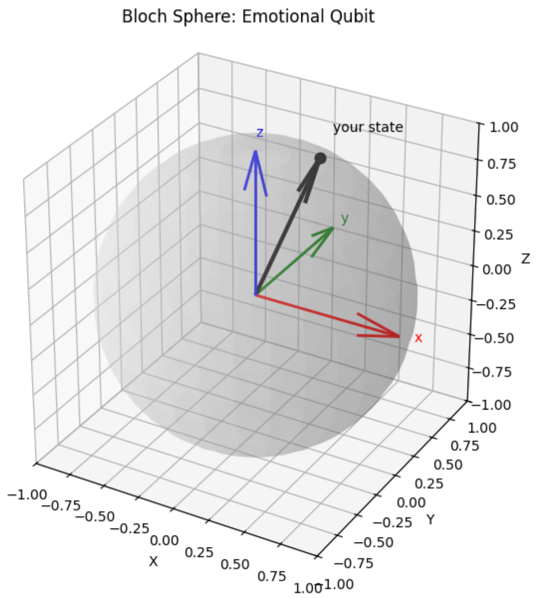

Figure 1: Bloch-sphere representation of emotional state. The polar angle θ encodes valence (negative to positive) and the azimuthal angle ϕ encodes tone or sarcasm phase.

2.3 Mapping Valence to θ

For emotional valence $v \in [-1, 1]$:

$$\theta(v) = \pi\left(\frac{1-v}{2}\right). \tag{5}$$

Thus:

- $v = -1 \Rightarrow \theta = \pi$: pure sadness.
- $v = +1 \Rightarrow \theta = 0$: pure happiness.
- $v = 0 \Rightarrow \theta = \pi/2$: perfect ambivalence.

2.4 Born-Rule Collapse

Measurement in the $\{|e_1\rangle, |e_2\rangle\}$ basis yields:

$$P(\text{sad}) = |\langle e_1|\psi\rangle|^2 = \cos^2\left(\frac{\theta}{2}\right), \tag{6}$$

$$P(\text{happy}) = |\langle e_2|\psi\rangle|^2 = \sin^2\left(\frac{\theta}{2}\right). \tag{7}$$

The user's message (emoji choice) corresponds to a stochastic projection onto one basis state according to these probabilities.

2.5 Density Matrix Representation

The pure-state density matrix is:

$$\rho = |\psi\rangle\langle\psi| = \begin{pmatrix} \cos^2\frac{\theta}{2} & \frac{1}{2}\sin\theta e^{-i\phi} \\ \frac{1}{2}\sin\theta e^{i\phi} & \sin^2\frac{\theta}{2} \end{pmatrix}. \tag{8}$$

The off-diagonal elements represent coherence (tone). After measurement, these vanish, analogous to emotional "decoherence"—the nuance is lost when only one emoji is observed.

2.6 Entropy of Expression

The Shannon entropy quantifies expressive uncertainty:

$$H(\theta) = -\left[\cos^2\left(\frac{\theta}{2}\right)\log_2\cos^2\left(\frac{\theta}{2}\right) + \sin^2\left(\frac{\theta}{2}\right)\log_2\sin^2\left(\frac{\theta}{2}\right)\right]. \tag{9}$$

Maximum entropy occurs at $\theta = \pi/2$ (neutral mood), and $H \to 0$ for pure states ($\theta = 0$ or π).

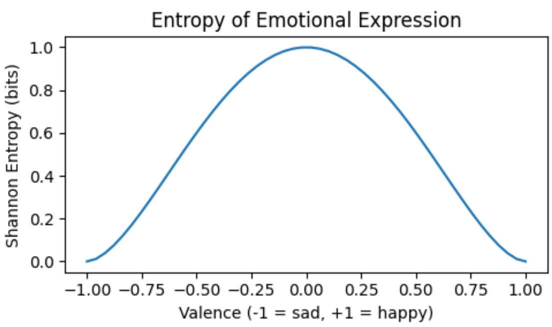

Figure 2: Entropy of expression versus valence. Ambivalence ($v \approx 0$) corresponds to maximal uncertainty, while extreme moods ($v = \pm 1$) are almost deterministic.

2.7 Tone Phase and Interference

Although $|\beta|^2$ is independent of ϕ in this measurement basis, ϕ becomes crucial if measured in a rotated basis (for example, "sincere" vs "sarcastic" happiness). In such cases, ϕ contributes interference terms via the off-diagonal elements in Eq. (8), altering the probability amplitude.

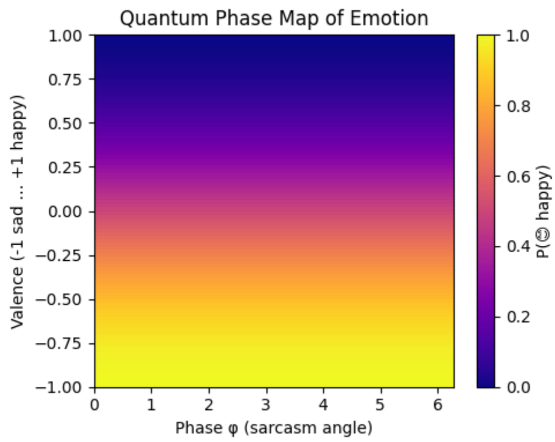

Figure 3: Phase map showing $P(\text{happy})$ as a function of valence v and sarcasm phase ϕ.

2.8 Multi-Emoji Superposition

For richer affective structure, we define an N-dimensional Hilbert space:

$$|\Psi\rangle = \sum_{k=1}^{N} \alpha_k |e_k\rangle, \quad \sum_{k=1}^{N} |\alpha_k|^2 = 1. \tag{10}$$

Each $|e_k\rangle$ represents a distinct emotional prototype (e.g., angry, sad, loving). For example:

$$|\Psi\rangle = 0.40|e_{\text{angry}}\rangle + 0.35|e_{\text{sad}}\rangle + 0.25|e_{\text{love}}\rangle. \tag{11}$$

The probability of expressing each emotion is $|\alpha_k|^2$. The entropy generalizes to:

$$H_N = -\sum_{k=1}^{N} |\alpha_k|^2 \log_2 |\alpha_k|^2. \tag{12}$$

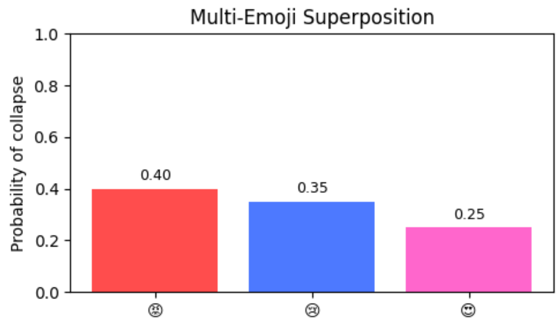

Figure 4: Multi-emoji probability distribution. Probabilities $|\alpha_k|^2$ represent the likelihood of each affective state collapsing into expression.

2.9 Temporal Collapse Simulation

Over time, repeated expressions correspond to independent measurements. If 200 trials are performed with probabilities from Eq. (3), the outcomes form a binary stochastic series. The relative frequencies converge to the theoretical $P(\text{sad})$ and $P(\text{happy})$ values.

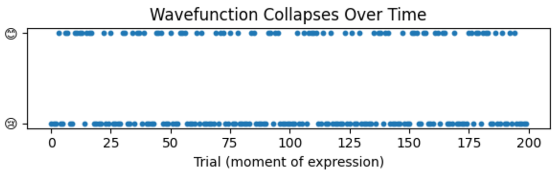

Figure 5: Temporal collapse of expression across 200 trials. Random collapses follow Born-rule probabilities.

3 Discussion

The Quantum Emoji Encoder formalizes emotional behavior as a quantum information process:

- **Superposition:** simultaneous presence of multiple emotional drives before communication.
- **Collapse:** forced choice of one emoji during message transmission.
- **Entropy:** measure of emotional ambiguity, maximized for mixed states.
- **Phase:** encodes tone, sarcasm, and contextual interference.

The off-diagonal terms of ρ quantify coherence, which is destroyed during measurement, explaining loss of nuance in digital emotion.

4 Future Work

Possible extensions include:

1. Defining a Hamiltonian H for emotional dynamics:
$$i\hbar \frac{d|\psi(t)\rangle}{dt} = H|\psi(t)\rangle,$$
where H encodes contextual social interaction.
2. Modeling emotional decoherence via Lindblad operators.
3. Treating multi-person conversations as entangled states with shared density matrices.
4. Extending entropy analysis to mutual information between interlocutors.

5 Conclusion

This work unifies emotion, information theory, and quantum mechanics. The derived framework quantitatively models digital expression as a quantum collapse process. Figures 1–5 illustrate how valence, tone, and uncertainty map onto quantum geometry and entropy landscapes. The approach demonstrates how quantum analogies can deepen computational representations of human emotion.

References

[1] J. R. Busemeyer and P. D. Bruza, *Quantum Models of Cognition and Decision*, Cambridge University Press, 2012.

[2] R. Franco, "The quantum probabilistic approach to cognition: A tutorial," *Frontiers in Psychology*, 2009.

[3] A. Khrennikov, *Ubiquitous Quantum Structure: From Psychology to Finance*, Springer, 2010.

[4] M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press, 2010.

[5] C. E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal*, vol. 27, pp. 379–423, 1948.

[6] E. T. Jaynes, "Information Theory and Statistical Mechanics," *Physical Review*, vol. 106, no. 4, pp. 620–630, 1957.