Computational Space Theory: A Unified Framework with Emergent Forces

Thomas Alexander Syrel

February 20, 2025

1 Foundations of CST

1.1 Evolution of Computational Nodes

$$\sigma_i(t + \delta t) = F(\sigma_i(t), \sigma_j(t), \ldots)$$

- Units: σ_i - dimensionless node state, t - seconds [s]

1.2 Local Computational Rate

$$\begin{aligned}
R(x) &= \frac{c^3}{8\pi G\rho(x)\ell^3} \quad \text{(Units: } s^{-1}) \\
[c^3] &= m^3/s^3 \\
[G] &= m^3/(kg \cdot s^2) \\
[\rho] &= kg/m^3 \\
[\ell^3] &= m^3 \\
\left[\frac{c^3}{G\rho\ell^3}\right] &= \frac{m^3/s^3}{(m^3/(kg \cdot s^2))(kg/m^3)(m^3)} = \frac{m^3/s^3}{m^3/s^2} = s^{-1}
\end{aligned}$$

1.3 Time Dilation

$$d\tau = \frac{dt}{\sqrt{1 - \frac{\rho(x)}{\rho_0}}}$$

where ρ_0 is a reference density with units $[kg/m^3]$.

2 Energy and Gravitation

2.1 Total Energy Formulation

$$E = \hbar R(x)S + \frac{1}{2}m\ell^2\left(\frac{dS}{dt}\right)^2 - \frac{Gm}{\ell}\int \rho(x)\, dV$$

Term	Expression	Units
Computational	$\hbar R(x) S$	$J \cdot s \cdot s^{-1} \cdot 1 = J$
Kinetic	$\frac{1}{2} m \ell^2 \left(\frac{dS}{dt}\right)^2$	$kg \cdot m^2 \cdot (s^{-1})^2 = J$
Gravitational	$-\frac{Gm}{\ell} \int \rho(x)\, dV$	$\frac{m^3}{kg \cdot s^2} \cdot kg \cdot \frac{kg}{m} \cdot m^3 = J$

Description of Gravitational Energy Derivation: The gravitational energy term in Computational Space Theory (CST) is designed to represent the interaction energy within the computational framework, ensuring consistency with physical units of energy (joules, $J = kg \cdot m^2/s^2$). The original formulation, $G \int \rho R c^2 \, dV$, resulted in incorrect units (m^5/s^5) due to the inclusion of the local computational rate $R(x) = \frac{c^3}{8\pi G \rho(x)}$ with units s^{-1}, which disrupted dimensional balance. To correct this, we reconsidered the gravitational energy in the context of CST's spatially distributed density $\rho(x)$.

The revised term, $-\frac{Gm}{\ell} \int \rho(x)\, dV$, integrates the density $\rho(x)$ over volume to yield total mass ($\int \rho \, dV = kg$), scaled by the gravitational constant $G = m^3/(kg \cdot s^2)$, a reference mass $m = kg$, and a characteristic length scale $\ell = m$ intrinsic to the computational nodes (as hinted in the kinetic term). Unit analysis confirms: $\frac{m^3}{kg \cdot s^2} \cdot kg \cdot m^{-1} \cdot kg = kg \cdot m^2/s^2 = J$. The negative sign aligns with gravitational potential energy conventions, indicating an attractive interaction.

This formulation eliminates $R(x)$ from the gravitational term, reserving it for the computational energy $\hbar RS$, where it appropriately modulates frequency-like behavior. The length scale ℓ introduces a spatial dependency, reflecting CST's node-based structure, while m serves as a mass parameter (e.g., a test mass or system mass), ensuring the term contributes to the total energy E as a physically meaningful quantity in joules.

3 Unification of Fundamental Forces

3.1 Electromagnetism (U(1))

$$\mathcal{L}_{\text{EM}} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} \quad [F_{\mu\nu}] = T = kg/(s^2 \cdot A)$$

3.2 Weak Force (SU(2))

$$\mathcal{L}_{\text{weak}} = -\frac{1}{4} W^i_{\mu\nu} W^{i\mu\nu} \quad [W^i_{\mu\nu}] = GeV/c = 1.78 \times 10^{-27} kg \cdot m/s$$

3.3 Strong Force (SU(3))

$$\mathcal{L}_{\text{QCD}} = -\frac{1}{4} G^a_{\mu\nu} G^{a\mu\nu} \quad [G^a_{\mu\nu}] = GeV^2 = 3.16 \times 10^{-35} kg^2 \cdot m^2/s^4$$

4 Mass Generation Mechanism

4.1 Computational Higgs Analogy

$$R(x) = \frac{R_0}{1 + \alpha\rho(x)} \quad \alpha = \frac{8\pi G}{c^4} \quad [\alpha] = s^2/(kg \cdot m)$$

$$[1 + \alpha\rho] = 1 + \frac{s^2}{kg \cdot m} \cdot \frac{kg}{m^3} = 1 + \frac{s^2}{m^4} \quad \text{(Inconsistent!)}$$

5 Quantum Uncertainty Framework

5.1 Heisenberg Principle

$$\Delta x \Delta p \geq \frac{\hbar}{2} \quad \text{(Units: } m \cdot kg \cdot m/s = J \cdot s = [\hbar])$$

In Computational Space Theory (CST), position (x) and momentum (p) are coupled through the emergent network. Determining one (e.g., x via the number of steps n) perturbs the dynamics of the other (e.g., p via the local density ρ_i), and vice versa, mirroring the quantum non-commutativity of position and momentum operators. This emergent uncertainty reflects an informational limit inherent to a single computational cycle, analogous to the Heisenberg Uncertainty Principle. Within the discrete network, the precise specification of position constrains the ability to resolve momentum due to the finite relational structure, while a precise momentum measurement disrupts the positional resolution, aligning with the fundamental trade-off encapsulated by the principle.

5.2 Entanglement

$$F = \langle\psi|\rho_{\text{CST}}|\psi\rangle \quad [F] = \text{Dimensionless (0-1)}$$

6 Physical Constants Derivation

6.1 Gravitational Constant

$$G = \frac{\hbar c^3}{\ell_p^2} \quad \left[\frac{\hbar c^3}{\ell_p^2}\right] = \frac{J \cdot s \cdot m^3/s^3}{m^2} = m^3/(kg \cdot s^2)$$

7 Hypothetical Mechanism of Space and Density Emergence

In this framework, space and density emerge from a discrete computational network devoid of predefined spatial structure. The fundamental entities are computational nodes interconnected by relational edges, forming a graph where emergent properties arise from local interactions. This section outlines a hypothetical mechanism by which geometry and density manifest, driven solely by the connectivity of the network.

The emergent density, denoted as ρ, is hypothesized to stem from the local connectivity density within the network. Specifically, ρ at a given node is proportional to the ratio of edges to nodes in its neighborhood, reflecting the intensity of computational interactions. Concurrently, space emerges as a geometric construct defined by the minimal path lengths between nodes, quantified as an effective distance. This distance establishes an emergent metric, transforming the abstract network into a spatially interpretable domain.

Mathematically, the local computational density at node i is defined as:

$$\rho_i = \frac{E_i}{N_i}$$

where E_i represents the number of edges connecting node i to its neighbors, and N_i is the number of neighboring nodes within a specified radius.

The emergent distance between nodes i and j, denoted d_{ij}, is given by:

$$d_{ij} = \min(\text{number of edges in shortest path from } i \text{ to } j)$$

This distance metric induces an effective geometry, allowing the mapping of the network into a continuous spatial representation.

The computational rate R at each node, reflecting the processing frequency, is inversely proportional to the emergent density:

$$R_i = \frac{R_0}{\rho_i}$$

where R_0 is a reference rate intrinsic to the network's baseline configuration.

Gravitational energy, emerging from the collective interactions, is posited as:

$$E_{\text{grav}} = -\frac{M^2}{d_{\text{eff}}}$$

where M is the total emergent mass, proportional to the sum of local densities over the network, and d_{eff} is the effective distance derived from averaged path lengths.

This mechanism suggests that spacetime and mass-energy distributions are not primitive but arise from the relational structure of computational units, offering a pathway to unify geometry and physical properties within a purely computational paradigm.