A Mathematical Theory of Location Gates (2025)

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Abstract

This paper introduces a formal mathematical framework for **location gates**: structures that induce non-local adjacency between spatially separated regions. By extending classical notions from Topology, Graph Theory, and Differential Geometry, we define gates as operators that modify both metric and connectivity. The resulting spaces exhibit hybrid discrete–continuous structure with applications to transport networks, computation, and theoretical physics.

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1. Introduction

Classical geometry assumes that distance is intrinsic and continuous. However, many real and theoretical systems violate locality:

- airline travel bypasses geographic continuity
- communication networks ignore physical distance
- theoretical constructs such as Wormhole connect distant spacetime regions

We formalize these phenomena as **location gates**, defined as mappings that collapse spatial separation.

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2. Preliminaries

Let (M, d)be a metric space.

We assume:

- $M$is a smooth manifold (for continuous models)
- or a finite set (for discrete models)

We denote standard distance by $d(x, y)$.

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3. Definition of a Location Gate

A **location gate** is an ordered pair $(a, b) \in M \times M$together with a cost parameter $\varepsilon \geq 0$.

It induces a modified metric:

$$d'(x, y) = \min\left(d(x, y),\ d(x, a) + \varepsilon + d(b, y),\ d(x, b) + \varepsilon + d(a, y)\right)$$

This definition ensures:

- symmetry
- non-negativity
- relaxation of geometric locality

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4. Graph-Theoretic Representation

We associate a graph $G = (V, E)$:

- $V = M$
- $E = E_{\text{local}} \cup E_{\text{gate}}$

Where:

- E_{local}encodes standard adjacency
- E_{gate}consists of edges (a, b)

This embeds the system into Graph Theory, allowing:

- shortest path analysis
- centrality measures
- network optimization

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5. Topological Consequences

From the perspective of Topology:

- a gate identifies neighborhoods of $a$and b
- the quotient space introduces **nontrivial connectivity**

In continuous settings, this resembles attaching a handle between regions of a manifold.

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6. Differential Structure

If $M$is a smooth manifold, gates induce:

- discontinuities in geodesics
- multi-valued shortest paths

- piecewise smooth trajectories

This connects to Differential Geometry and generalized geodesic flows.

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7. Gate Networks

Let $\mathcal{G} = \{(a_i, b_i)\}_{i=1}^{k}$ be a set of gates.

We define:

- gate density
- accessibility function
- clustering induced by gates

Theorem (informal):
A sufficiently dense gate set transforms a metric space into a *small-world structure* with logarithmic diameter.

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8. Physical Interpretation

In General Relativity, analogous structures arise as spacetime shortcuts.

However, the present framework:

- does not assume physical realizability
- treats gates as abstract operators
- applies equally to digital and conceptual systems

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9. Applications

9.1 Transport Systems

- modeling air travel vs road distance
- optimizing logistics with hubs

9.2 Computer Networks

- routing with long-range links
- latency minimization

9.3 Game and Simulation Design

- teleportation mechanics

- non-Euclidean level design

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10. Open Problems

- Stability of geodesics under dynamic gates
- Probabilistic gate distributions
- Embedding gate spaces into Euclidean representations
- Physical constraints for realizable gates

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11. Conclusion

Location gates provide a unifying abstraction for systems in which **distance is no longer fundamental**. By integrating tools from topology, graph theory, and geometry, we obtain a flexible framework capable of describing both real-world networks and speculative spatial structures.