

A Coordination Framework for Near Real-Time Mosaic Imaging using Large LEO Satellite Constellations

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Abstract



While Low Earth Orbit (LEO) constellations provide superior spatial resolution, their narrow fields of view and rapid orbital velocities currently prohibit the generation of synchronised, near-real-time large-area mosaics. To resolve this coordination gap, this research proposes a computational framework that transforms uncoordinated LEO assets into a unified "**Virtual GEO**" sensor. By integrating deterministic orbital dynamics with a strict tile-based geometric coordination algorithm, the protocol mathematically synchronises multiple satellites to capture contiguous regional tiles. Validated through high-fidelity simulation, this approach eliminates traditional store-and-forward latency, enabling near-live, wide-area Earth Observation for time-critical missions such as disaster response and environmental monitoring.

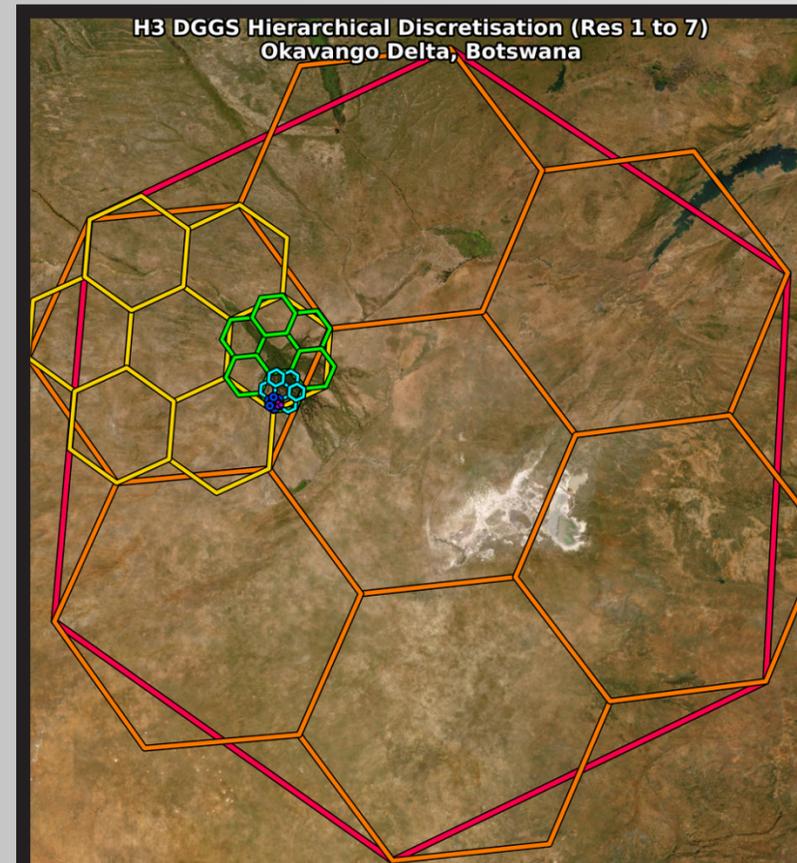
Current Bottleneck



Legacy "**store-and-forward**" architectures introduce critical **24-72 hour** latencies and massive data redundancy, rendering uncoordinated LEO constellations ineffective for time-critical emergency response.

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Hierarchical Spatio-Temporal Discretisation
of the Okavango Delta

Simulation & Validation Strategy



The framework is validated through a high-fidelity Python/Orekit pipeline simulating varying constellation densities (**N=5 to 100**) to quantify gains in reconstruction latency, data redundancy, and mosaic completeness against traditional baselines.

Proposed Approach



To overcome the massive latency of traditional post-hoc image stitching, the proposed framework shifts from an image-centric pipeline to a **predictive, geometry-centric** coordination model.

- **Geodesic Grid Modelling (DGGS):** The continuous target region of Botswana is mathematically discretised using the H3 Hexagonal Spatial Index. The figure demonstrates the "Aperture-7" fractal property, telescoping from a macro-level grid (**Resolution 1**) down to the exact Field of View (FOV) footprint of a LEO sensor (**Resolution 7, ≈ 1.22 km edge length**).
- **Deterministic Coverage Optimisation:** Instead of relying on random satellite captures, the algorithm maps deterministic LEO orbital ground-tracks (propagated via SGP4/Orekit) directly to these static hexagonal indices. This reduces the heavy computational burden of pixel-level image stitching into a highly efficient, algorithmic set-cover optimisation problem.
- **Robust "Fail-Signal" Semantics:** Treating the constellation as a unified "Virtual GEO" system, the framework enforces contiguous geometric constraints. If a specific Resolution-7 tile is obscured by cloud cover or missed due to sensor error, it triggers an explicit "fail signal", prompting the coordination algorithm to dynamically task the next available satellite to capture the missing index.

Societal Impact & "Virtual GEO"



By bridging astrodynamics and computational geometry, this open-source framework enables a "Virtual GEO" capability that provides Botswana and Africa with the high-resolution, near-real-time intelligence critical for rapid disaster response and national resource management.

References

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