Real-time Spatial-temporal Traversability Assessment via Feature-based Sparse Gaussian Process

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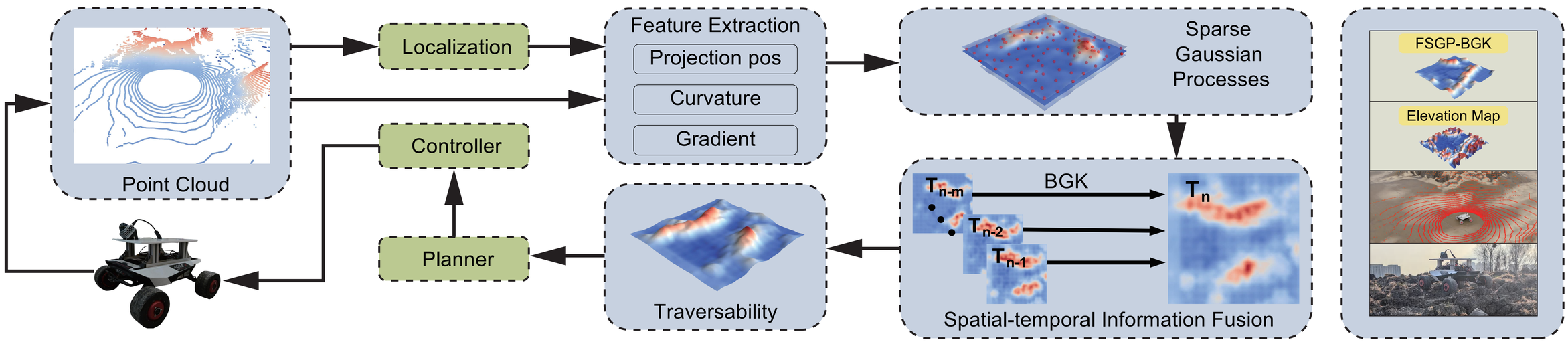
Motivation

- **Safety-critical:** Off-road robots require reliable traversability estimation to avoid hazards and enable safe, efficient navigation.
- **Prior gap:** Single-frame point clouds and inadequate temporal fusion yield unstable estimates and high computational cost, preventing real-time performance.

Contribution

- An efficient feature-driven SGP pipeline for traversability analysis with uncertainty modeling.
- A spatial–temporal BGK inference framework for adaptive mapping in dynamic environments.
- Integration into an autonomous navigation system with open-source implementation and real-world validation.

Methodology



Experiments

Exp1: We develop terrain generators, build simulators, and conduct navigation experiments across different simulation platforms.

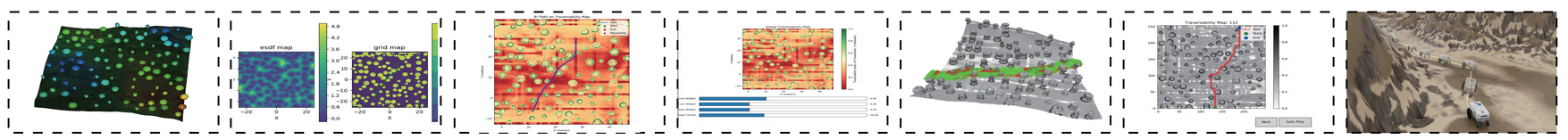


TABLE I: Different Terrains.

Type	Method	Average Mean	Average Variance
Hilly	SG	0.2604	0.0392
	FSG	0.2321	0.0345
	FSGP-BGK	0.1237	0.0085
Forest	SGP	0.1831	0.0245
	FSGP	0.1777	0.0227
	FSGP-BGK	0.1687	0.0213
Ruin	SGP	0.2003	0.0239
	FSGP	0.1965	0.0219
	FSGP-BGK	0.1831	0.0206
Road	SGP	0.1694	0.0373
	FSGP	0.1434	0.0328
	FSGP-BGK	0.1051	0.0240
Indoor	SGP	0.2455	0.0451
	FSGP	0.2537	0.0429
	FSGP-BGK	0.1978	0.0420

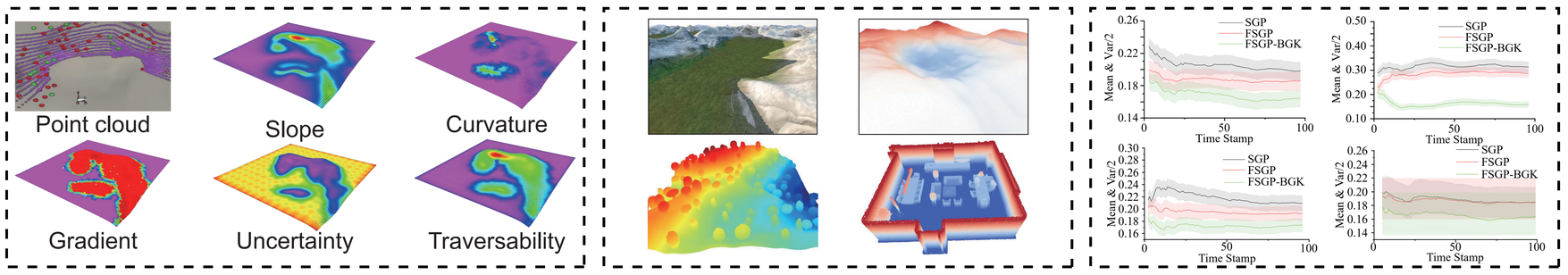
TABLE II: Comparison with EM Methods.

Metho	Mean	Variance	Avg. Runtime (ms)
FSGP-BGK	0.1139	0.0333	33.84
EM	0.1953	0.0422	107.85

TABLE III: Resource Usage.

	FSGP-BGK	FSGP-Accumulation
Memory Usage (%)	9.4	9.4
GPU Memory Usage (%)	25	36
Processing Time (ms)	29.16	42.37

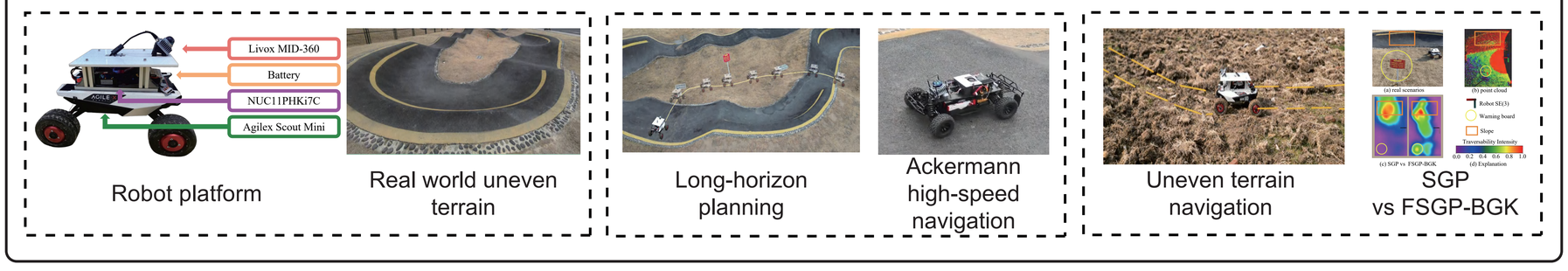
Exp2: We validate the algorithm using the same baseline Gazebo simulator and conduct comparative experiments on different terrain dataset.



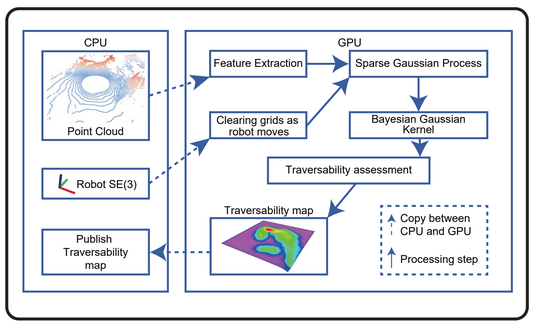
Feature-based SGP results in an uneven environment.

Quantitative test terrains and results.

Exp3: We conduct real-robot experiments, including perception and navigation on real uneven terrain.



Exp4: Parallelize traversability map.



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