Contact with Rough Terrain & Free-Formed Objects

Hypothesis
Sparse 3D foothold/handhold contact affordances can be detected, modeled, and mapped in real-time using curved surface patches.

Sparsity of Contact Affordances Robots requires
1. Modeling local contact surface areas
2. Online perception algorithms to find them
3. Handling uncertainty

Environment Representation

Curved Patch Modeling [1]
- Detailed models for 10 bounded curved-surface patch types for contact regions
- Minimal geometric parametrizations: curvature, spatial pose, and bounds
- Foot/hand-sized boundaries

Input
- 3D point cloud from a range sensor
- The corresponding Gaussian uncertainty as a covariance

Output
The fitted curved patches and their Gaussian distribution model uncertainty (covariance) in patch parameter space

Patch Fitting with First-Order Uncertainty Propagation

First-Order Uncertainty Propagation: $\Sigma' = J \Sigma J^T$, for $f(x)$

Applications to Foothold/Handhold Contacts

Applications
- Contact risk analysis using Multivariate Gaussian Distribution Metrics to measure the magnitude of uncertainty
- Reasoning about contacts by integrating the patch-system into a path planner
- A time/space efficient patch-based SLAM system for locomanipulation tasks

References

All Sourcecode Provided as the Open-Source Surface Patch Library (SPL): http://dkanou.github.io/projects/spl/index.html [1,2]

Point Clouds and their Gaussian Uncertainty Modeling

Patch Fitting
Real-time nonlinear fitting algorithm to neighborhoods of range data, including quantified uncertainty (~0.6ms)

From Range Sensing to Contact Patches

Applications to Foothold/Handhold Contacts

Contacts at Rough Terrain & Free-Formed Objects

The ref frame

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