Surface Patches for Rough Terrain Perception

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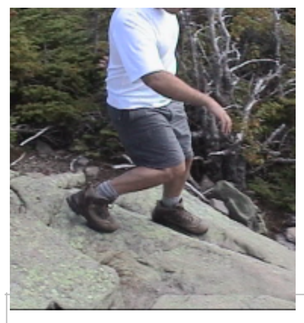
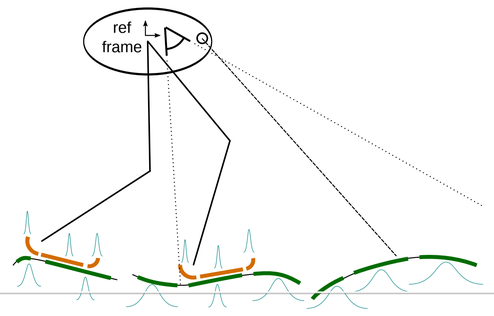
All Sourcecode Provided as the Open-Source Surface Patch Library (SPL)

Perceiving Rough Terrain

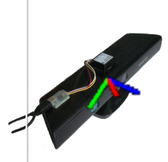


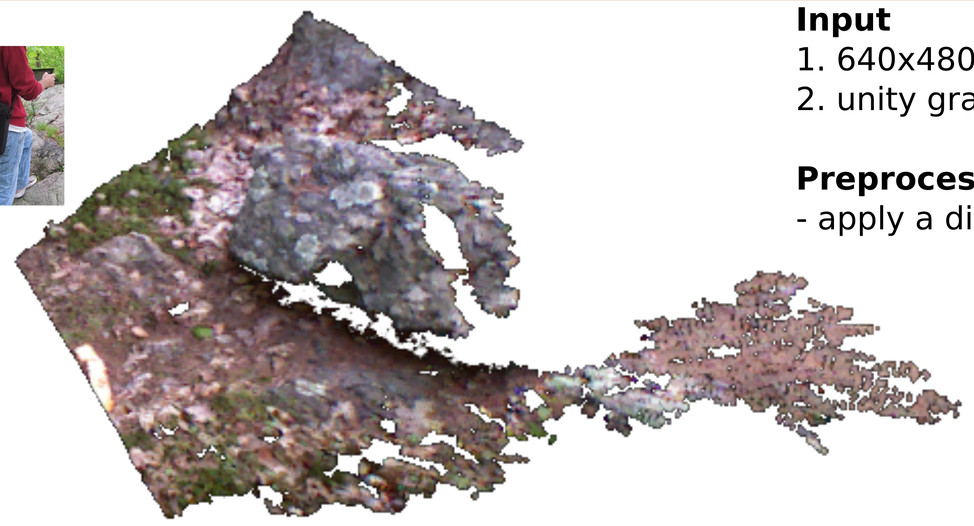


Hypothesis
Sparse 3D footfall affordances can be detected, modeled, and mapped in real-time using curved surface patches.

Sparsity of Footholds for Legged Robots requires
1. modeling local contact surface areas
2. online perception algorithms to find them
3. handling uncertainty

Range Sensing and IMU

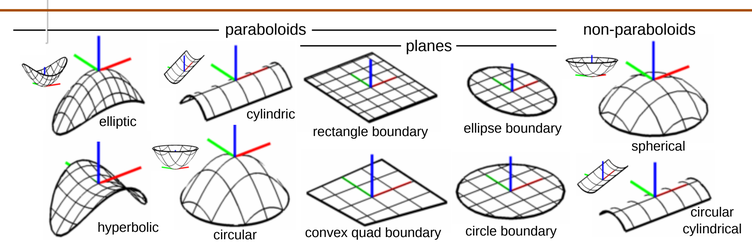


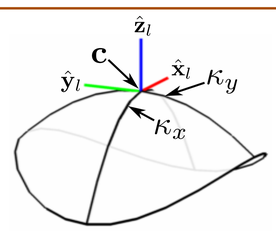


Input
1. 640x480 3D point cloud from depth camera
2. unity gravity vector from IMU

Preprocessing
- apply a discontinuity-preserving bilateral filter

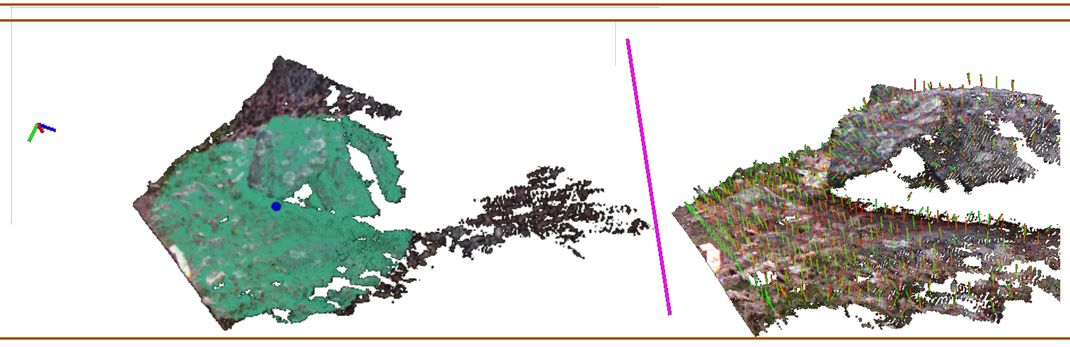
Bounded Curved Patches





Patch Modeling [1]
- detailed models for 10 bounded curved-surface patch types for contact regions
- minimal geometric parametrizations: *curvature*, *spatial pose*, and *bounds*
- foot-sized boundaries

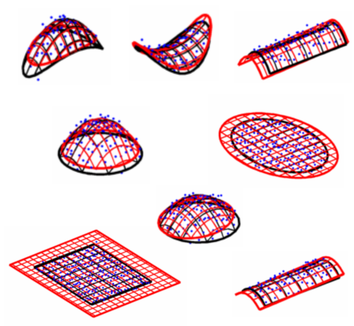
Saliency

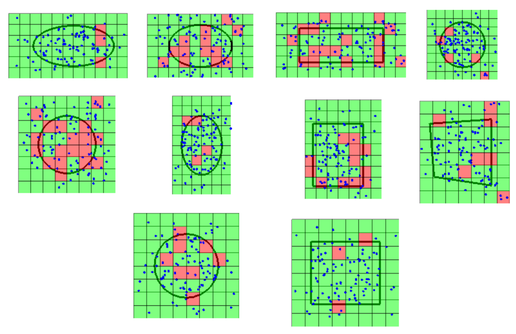


Measures of Saliency [3]
1. Distance to Estimated Fixation Point
2. Difference of Multiscale Normals
3. Difference of Normal-Gravity
4. Curvature Limits

Timing: ~35ms, *dominated by ~30ms for normal computation using Integral Images*

Patch Fitting and Validation



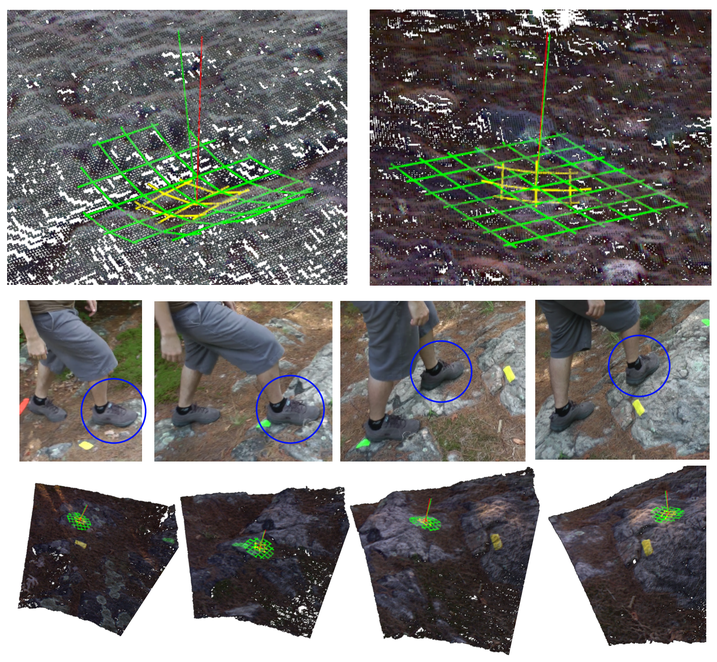


Patch Fitting [1]
real-time nonlinear fitting algorithm to neighborhoods of range data, including quantified uncertainty

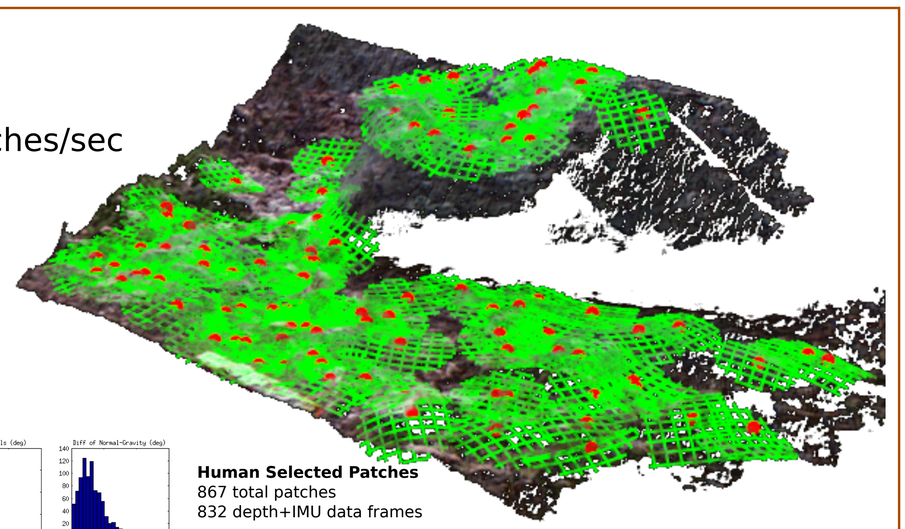
Patch Validation [2]
1. patch fit quality (residual)
2. fidelity to data (coverage)

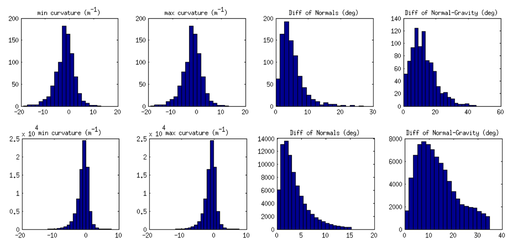
Timing: *~0.83ms per neighborhood with 50 points*

Bio-Inspired Sparse Surface Segmentation



Finding ~700 patches/sec

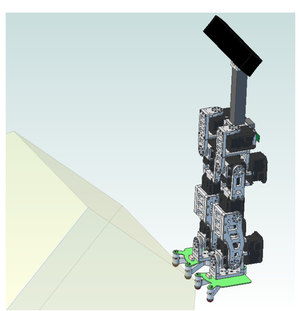




Human Selected Patches
867 total patches
832 depth+IMU data frames

Automatically Fit Patches
82052 total patches
832 depth+IMU data frames
(same frames as above)

Future Work



Patch Tracking [4,5]
- integrate with Moving Volume KinectFusion

Mini Biped
- depth+IMU camera
- feet to negotiate rough terrain

Goal: perception as part of a real-time foothold selection system

References

[1] "Curved Surface Contact Patches with Quantified Uncertainty", *Vona, Kanoulas, IROS 2011*
[2] "Sparse Surface Modeling with Curved Patches", *Kanoulas, Vona, ICRA 2013*
[3] "Bio-Inspired Rough Terrain Contact Patch Perception", *Kanoulas, Vona, Under Submission*
[4] "KinectFusion: Real-Time Dense Surface Mapping and Tracking" *Newcombe, Izadi, Hilliges, Molyneaux, Kim, Davison, Kohli, Shotton, Hodges, Fitzgibbon, ISMAR 2011*
[5] "Moving Volume KinectFusion", *Roth, Vona, BMVC 2012*