Comparison of constraints in different environments

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1 Overview

Key results:

- planar constraints with long walls reduce drift;
- segmented walls allow, and even increase drift;
- when points lie loosely on planes and plane parameters are free to adjust themselves, angle constraints improve orthogonality.

Outstanding issues:

- when system gets large (>200 vertices, 1000 edges) and no loop closures occur (ie corridor, corner), gauss-newton takes many iterations to converge.

2 Results

Simulation details:

- odometry, points measurement and plane angle constraint standard deviations were held constant
- the same level of noise was used in generating measurements and in the estimation;
- measurements were processed incrementally;
- gauss-newton was used;
- simulation was run with a) no constraints, b) planar constraints and c) planar and angle constraints;
- simulation was run with two levels of $\sigma_{plane-plane-angle}$, ie points very close to planes & points loosely on planes (ground truth).

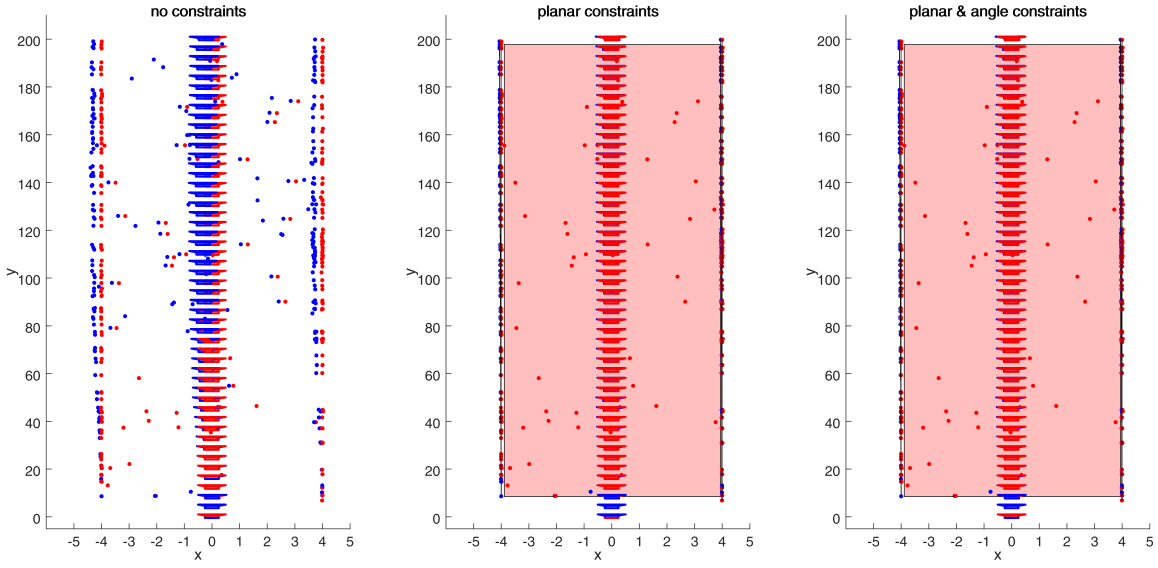

Figure 1: Comparison in corridor with ground, left and right planes (images not to scale). Points tightly distributed around planes. Angle constraints: left and right planes orthogonal to ground and parallel to one another. Drift is reduced by planar constraints.
$\sigma_{odometry} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}, \pi/90\text{rad}, \pi/90\text{rad}, \pi/90\text{rad}]$
$\sigma_{measurement} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}]$
$\sigma_{point-plane} = 0.01\text{m}$
$\sigma_{plane-plane-angle} = \pi/60\text{rad}$

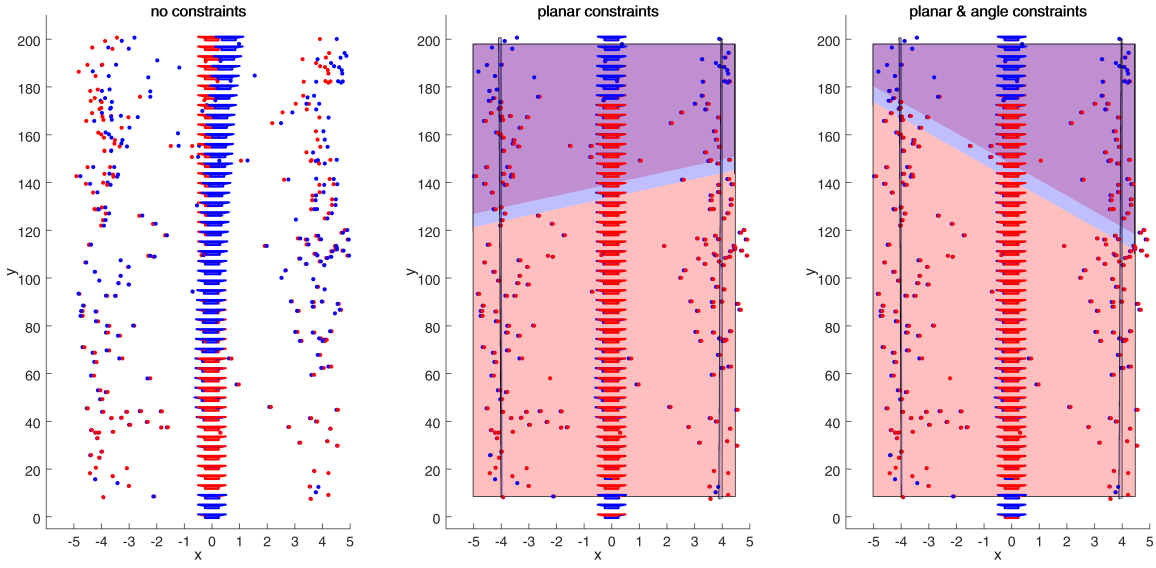

Figure 2: Comparison in corridor with ground, left and right planes (images not to scale). Points loosely distributed around planes. Angle constraints: left and right planes orthogonal to ground and parallel to one another. Drift is reduced by planar constraints.
$\sigma_{odometry} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}, \pi/90\text{rad}, \pi/90\text{rad}, \pi/90\text{rad}]$
$\sigma_{measurement} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}]$
$\sigma_{point-plane} = 0.5\text{m}$
$\sigma_{plane-plane-angle} = \pi/60\text{rad}$

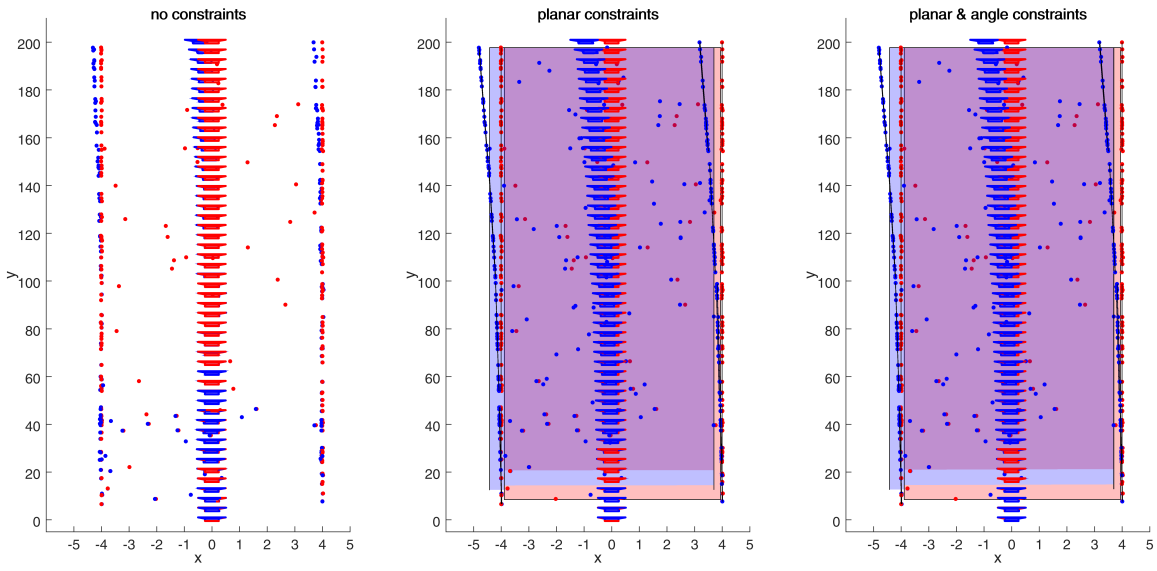

Figure 3: Comparison in corridor with ground, 4 left and 4 right planes (images not to scale). Points tightly distributed around planes. Angle constraints: wall planes orthogonal to ground and parallel to directly opposite plane. Drift is not reduce by planar constraints - seems to be increasing based on figure but this is due to random seed differing, due to different system sizes. More trials show drift is the same..
$\sigma_{odometry} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}, \pi/90\text{rad}, \pi/90\text{rad}, \pi/90\text{rad}]$
$\sigma_{measurement} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}]$
$\sigma_{point-plane} = 0.01\text{m}$
$\sigma_{plane-plane-angle} = \pi/60\text{rad}$

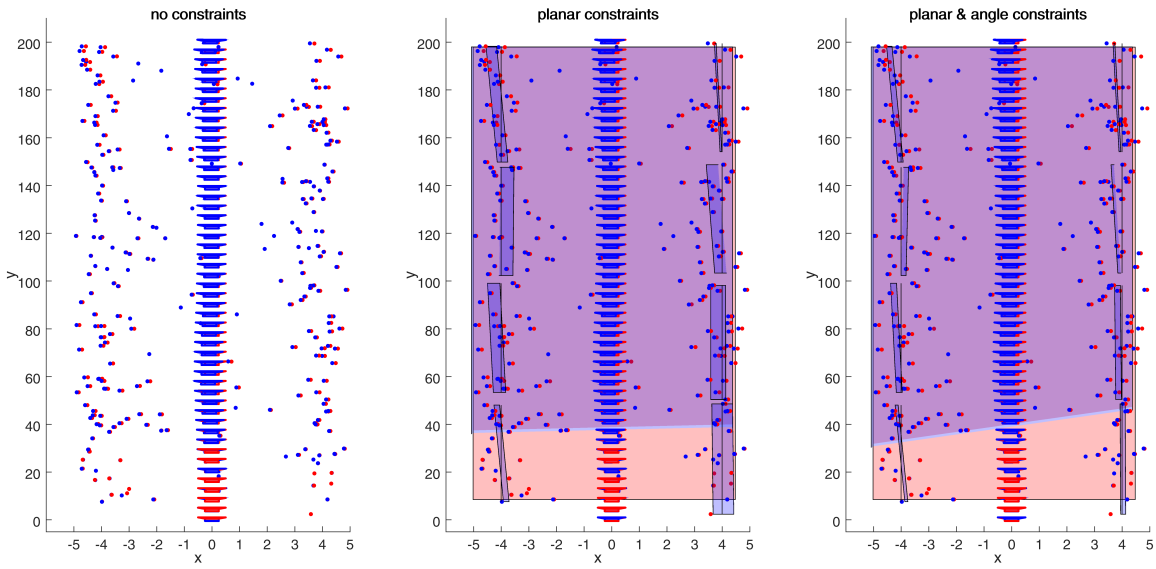

Figure 4: Comparison in corridor with ground, 4 left and 4 right planes (images not to scale). Points loosely distributed around planes. Angle constraints: wall planes orthogonal to ground and parallel to directly opposite plane. Angle constraints improve orthogonality of walls with ground.
$\sigma_{odometry} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}, \pi/90\text{rad}, \pi/90\text{rad}, \pi/90\text{rad}]$
$\sigma_{measurement} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}]$
$\sigma_{point-plane} = 0.5\text{m}$
$\sigma_{plane-plane-angle} = \pi/60\text{rad}$

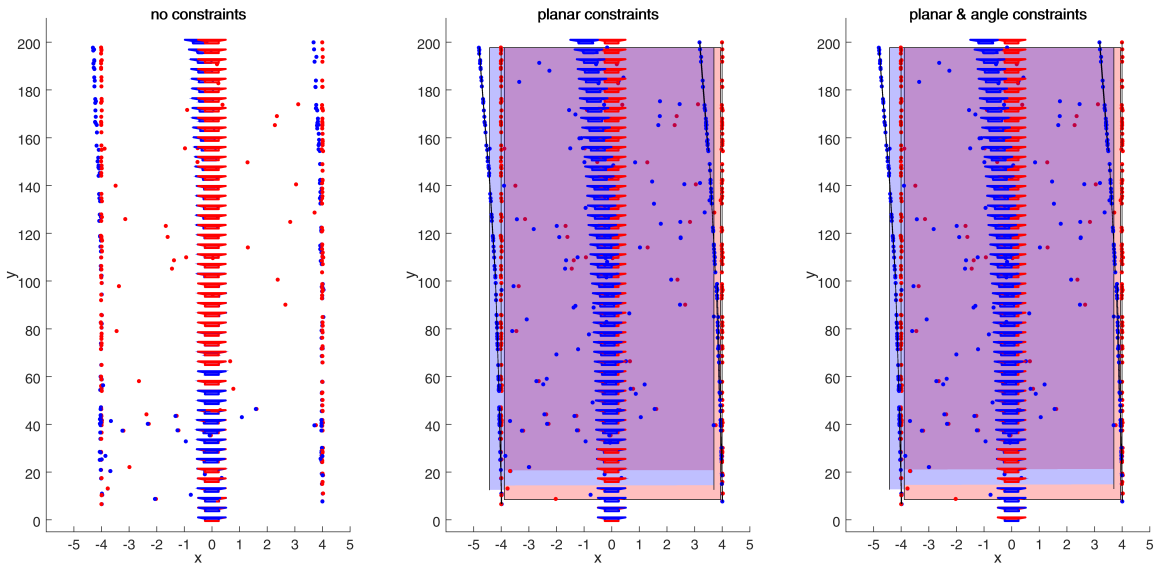

Figure 5: Comparison in corridor with ground, 4 left and 4 right planes (images not to scale). Points tightly distributed around planes. Angle constraints: wall planes orthogonal to ground and parallel to 3 closest opposite planes. Adding more angle constraints has no effect. Further tests showed that reducing $\sigma_{plane-plane-angle}$ had no effect either.
$\sigma_{odometry} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}, \pi/90\text{rad}, \pi/90\text{rad}, \pi/90\text{rad}]$
$\sigma_{measurement} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}]$
$\sigma_{point-plane} = 0.01\text{m}$
$\sigma_{plane-plane-angle} = \pi/60\text{rad}$

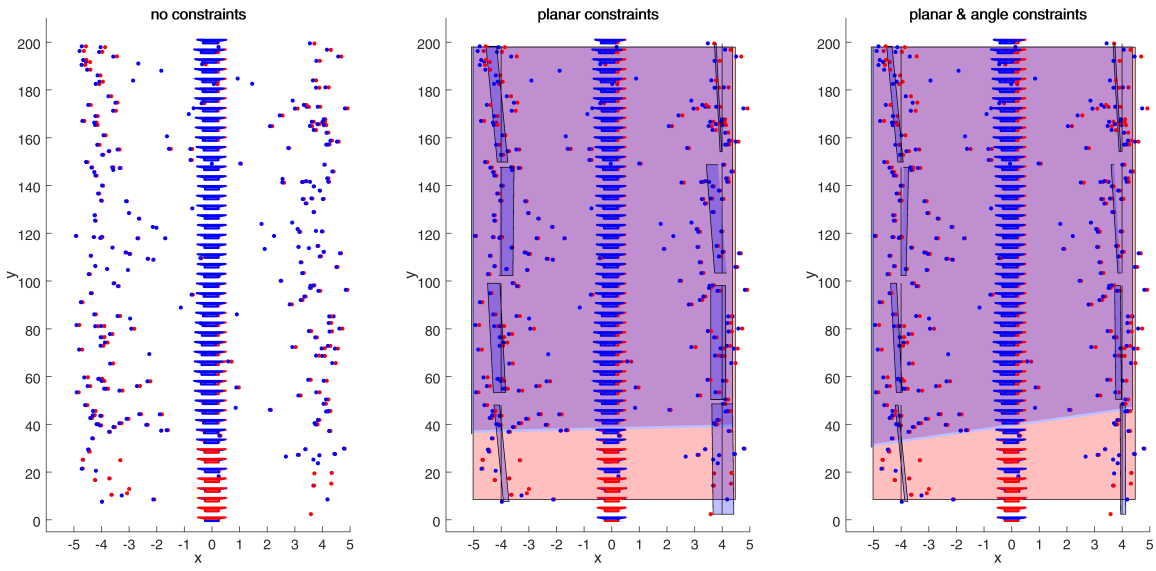

Figure 6: Comparison in corridor with ground, 4 left and 4 right planes (images not to scale). Points loosely distributed around planes. Angle constraints: wall planes orthogonal to ground and parallel to 3 closest opposite planes. Drift lower with no constraints. Adding more angle constraints has no effect. Further tests showed that reducing $\sigma_{plane-plane-angle}$ had no effect either.
$\sigma_{odometry} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}, \pi/90\text{rad}, \pi/90\text{rad}, \pi/90\text{rad}]$
$\sigma_{measurement} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}]$
$\sigma_{point-plane} = 0.5\text{m}$
$\sigma_{plane-plane-angle} = \pi/60\text{rad}$

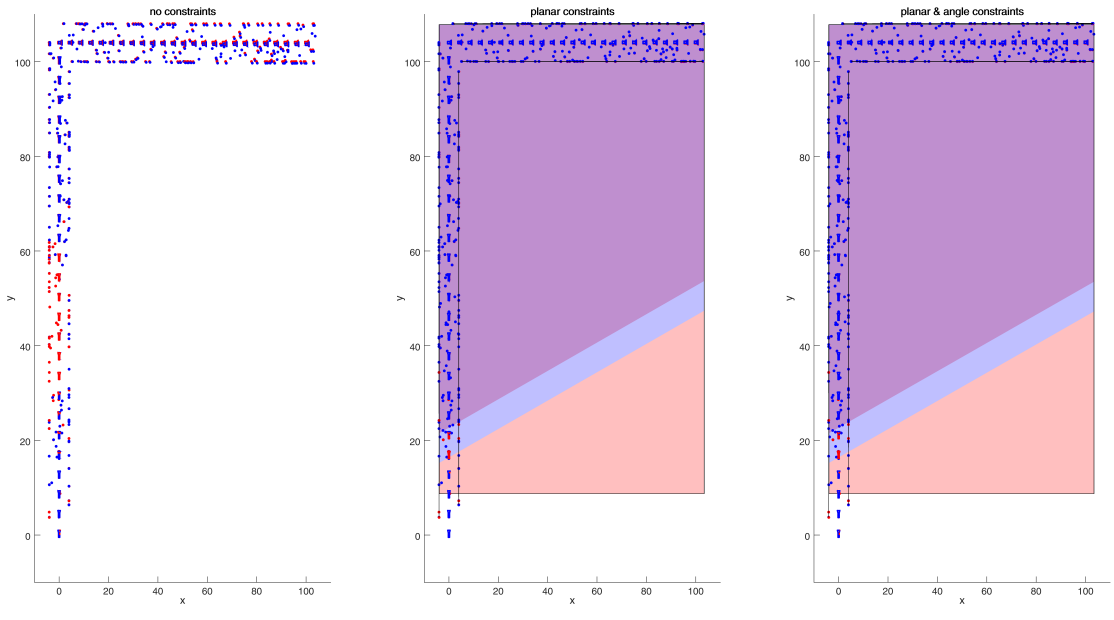

Figure 7: Comparison in corner with ground, 2 left and 2 right planes (images not to scale). Points tightly distributed around planes. Angle constraints: wall planes orthogonal to ground and parallel to opposite plane and orthogonal to connected plane. Planar constraints reduce drift.
$\sigma_{odometry} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}, \pi/90\text{rad}, \pi/90\text{rad}, \pi/90\text{rad}]$
$\sigma_{measurement} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}]$
$\sigma_{point-plane} = 0.01\text{m}$
$\sigma_{plane-plane-angle} = \pi/60\text{rad}$

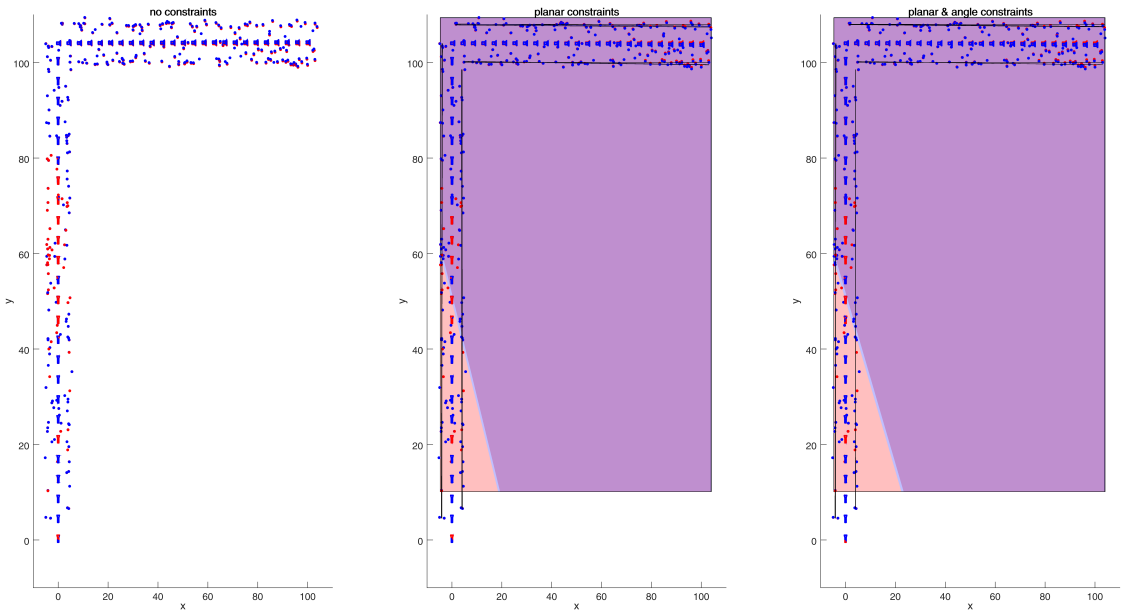

Figure 8: Comparison in corridor with ground, 4 left and 4 right planes (images not to scale). Points loosely distributed around planes. Angle constraints: wall planes orthogonal to ground and parallel to opposite plane and orthogonal to connected plane.
$\sigma_{odometry} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}, \pi/90\text{rad}, \pi/90\text{rad}, \pi/90\text{rad}]$
$\sigma_{measurement} = [0.02\text{m}, 0.02\text{m}, 0.02\text{m}]$
$\sigma_{point-plane} = 0.5\text{m}$
$\sigma_{plane-plane-angle} = \pi/60\text{rad}$