Information-Driven Adaptive Structured-Light Scanners

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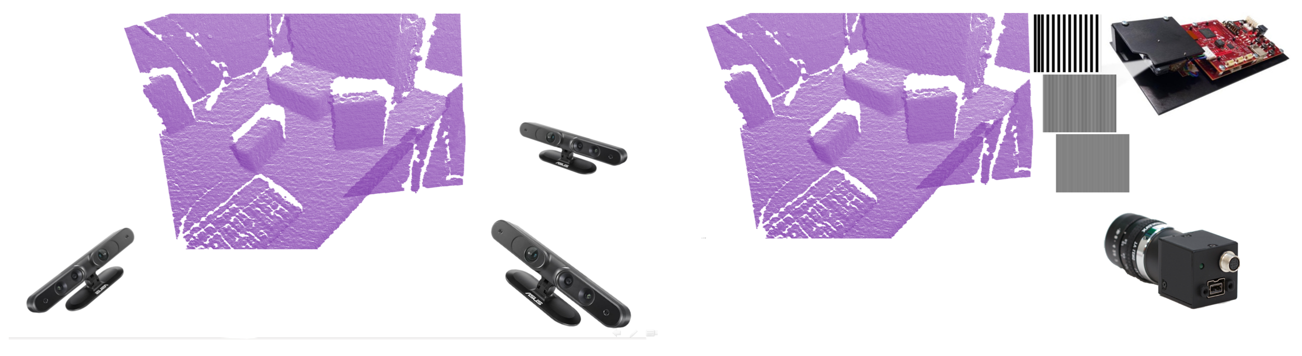
Overview

1. Adaptive 3D sensors via focused mutual information (MI) maximization.
2. Novel generative model for structured light scanners.
3. Estimate MI, demonstrate pattern selection for
   (a) Pose estimation (“localization“)
   (b) Range estimation (”mapping“).

Sensor Planning Inside the Sensor

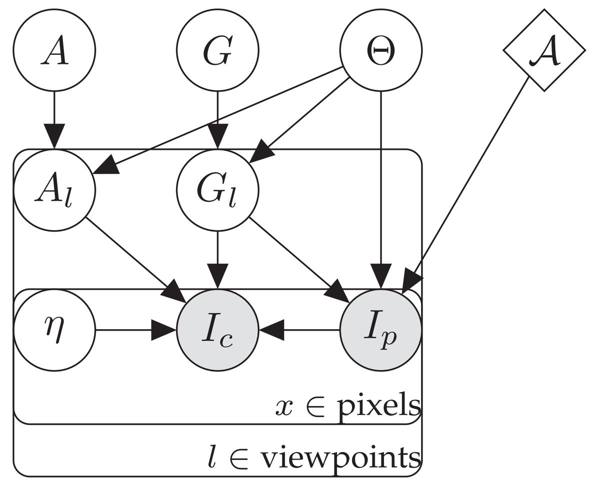


Where to place sensor

How to operate sensor

Model

- A, G - Global appearance and geometry, respectively.
- A_l, G_l - Local (viewpoint-) appearance and geometry.
- $\mathcal{A}$ - the decision of which pattern to project.
- I_p - the projector image
- I_c - camera image.



We use an affine-Gaussian illumination model per pixel,

$$I_c(x) = a(x) I_p\left(\Pi_{r,\Theta}(x)\right) + b(x) + \eta(x)$$

a, b, η have a Gaussian distribution.

Using this model we compute pixelwise mutual information

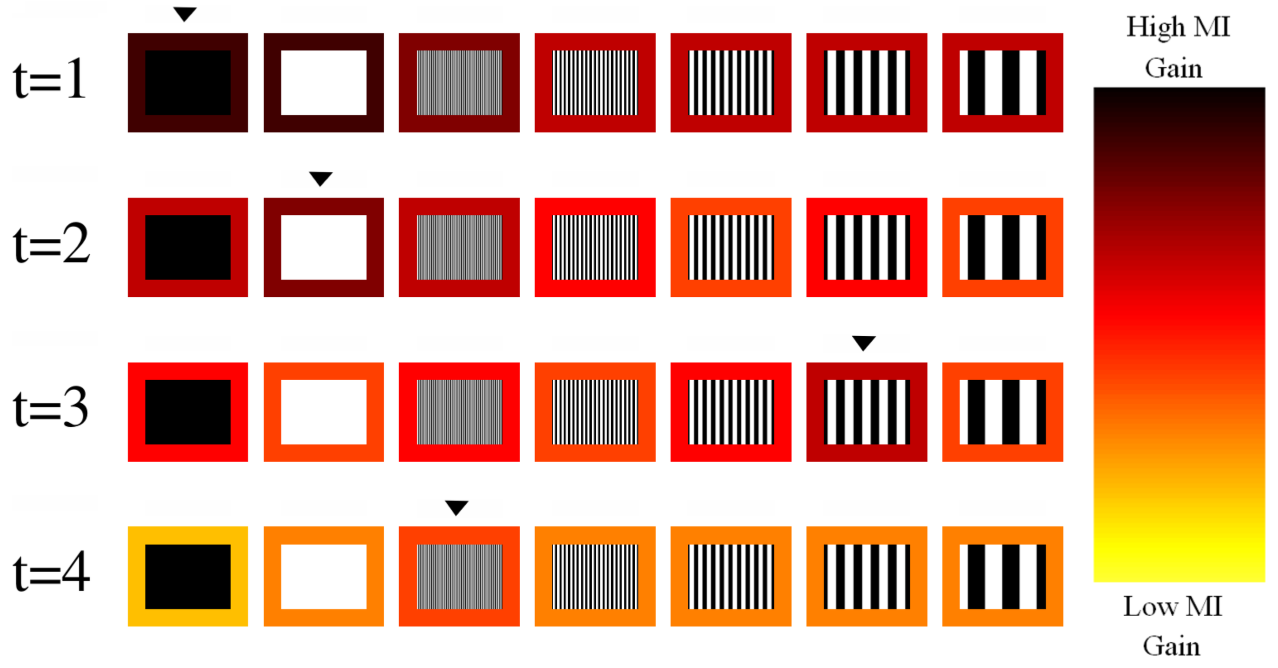
$$\mathcal{I}(I_c; G, \theta) = \sum_{G,\theta} \sum_{I_c|G,\theta} log \frac{p(I_c|G,\theta)}{p(I_c)}$$

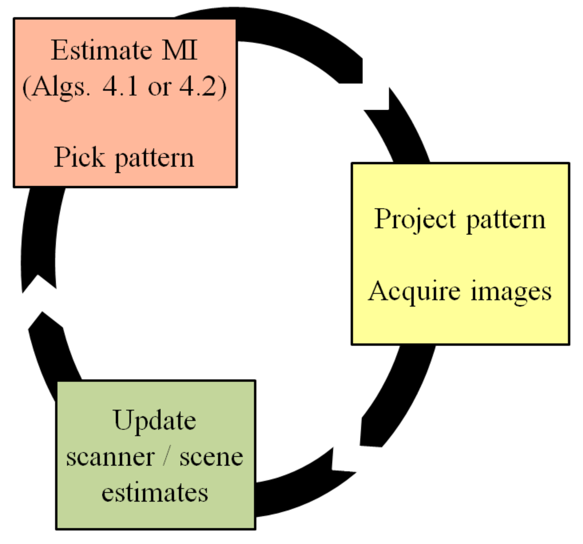
Computation per pixel via GPU – two loops:

- Estimate $p(I_c)$,
- Estimate $p(I_c|G,\theta)$, aggregate $\mathcal{I}(I_c; G, \theta) = \sum_{G,\theta}$

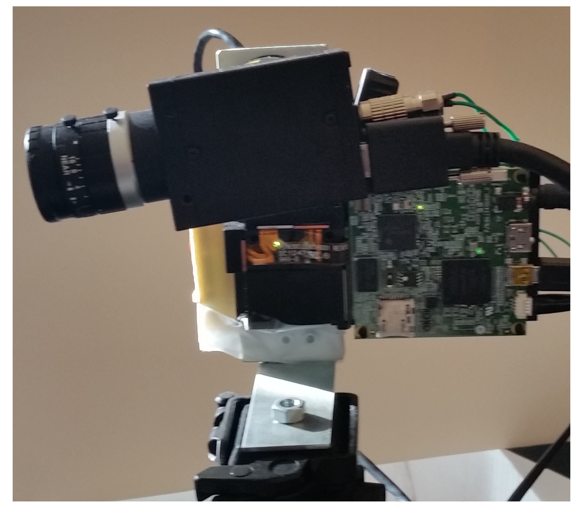
Greedy MI Pattern Selection

Estimate MI gain for the next pattern, then project the best one:





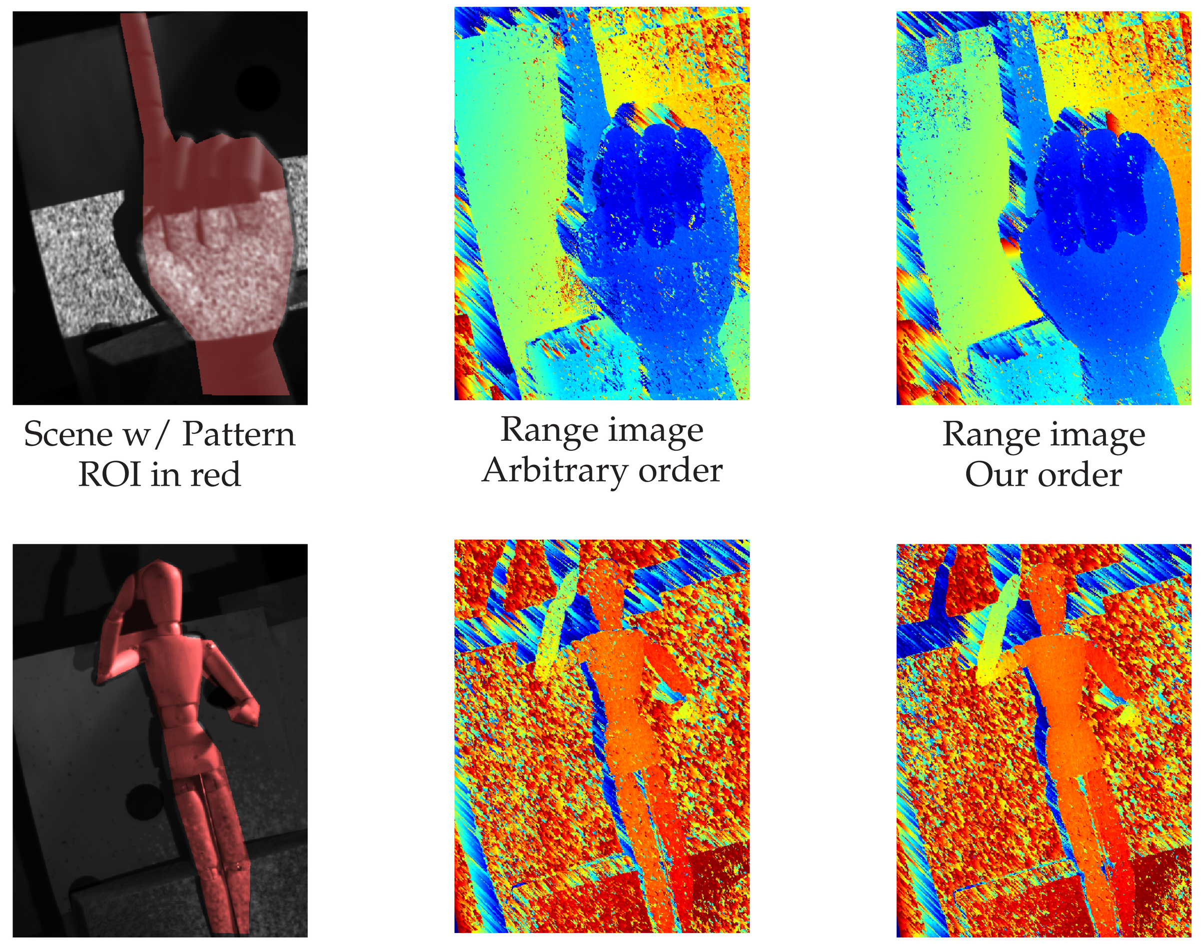
Open-Loop w/ Feedback



Setup

Results - Range Estimation

- (Mapping phase in SLAM)



Scene w/ Pattern ROI in red | Range image Arbitrary order | Range image Our order

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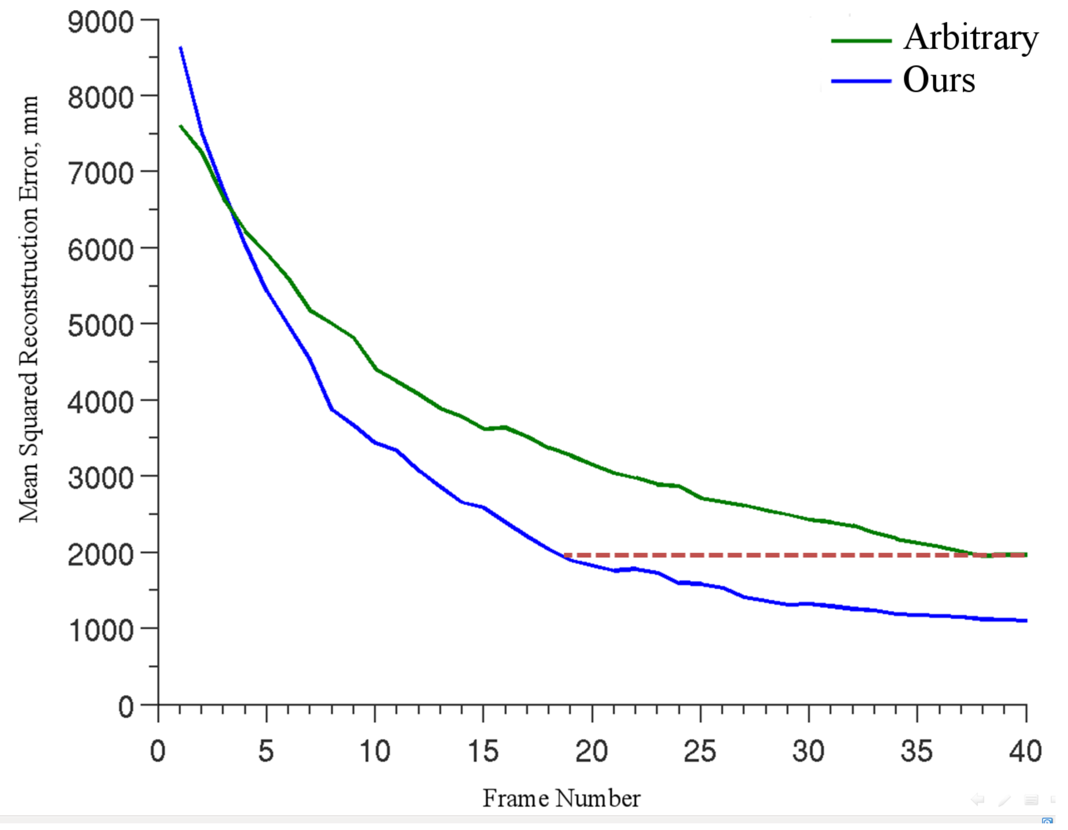
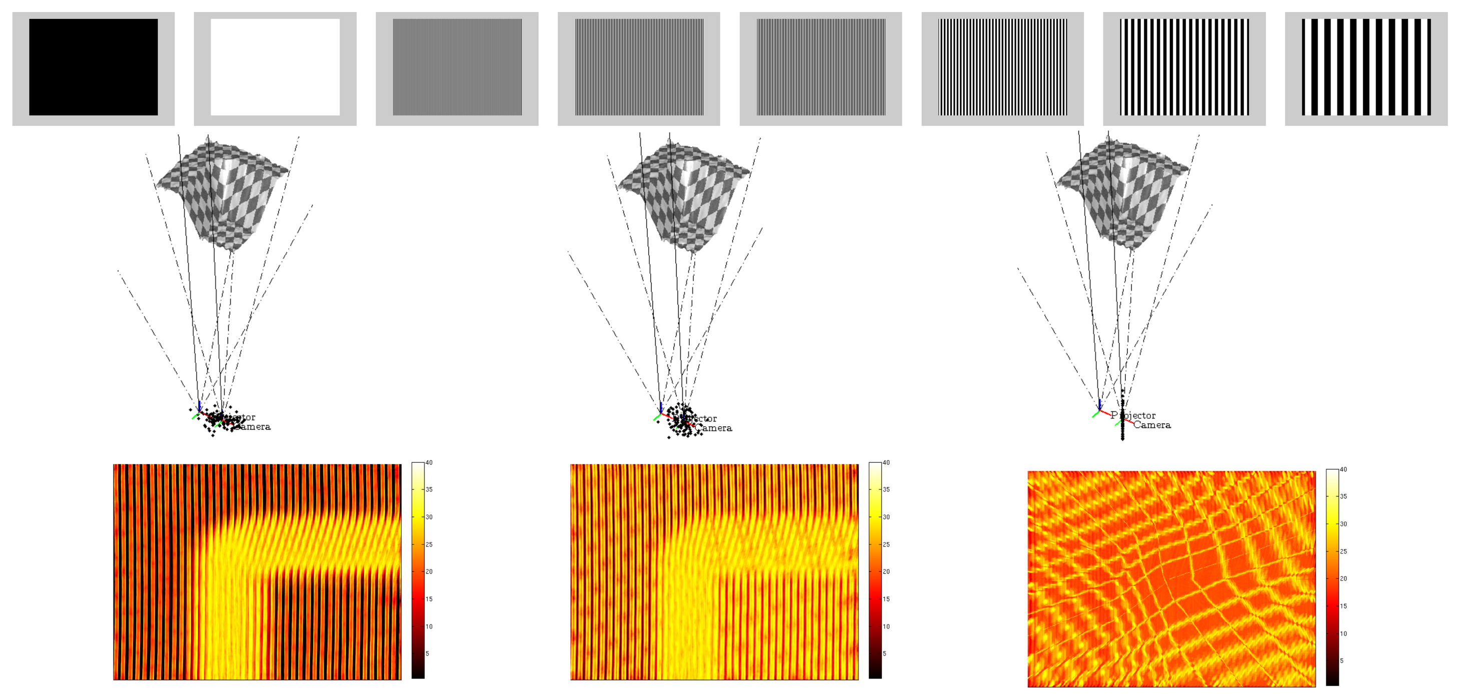


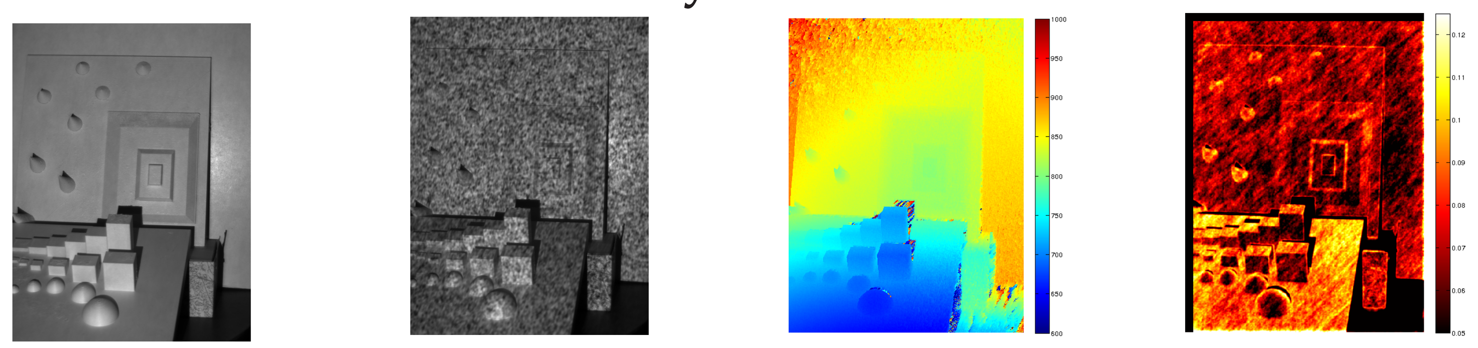
Results - Pose Estimation

- (Localization phase in SLAM)
- Assume scene is approximately known.
- Localize scanner with some initial uncertainty. (look at translation because it is intuitive).



Uncertainty in XY plane | Isotropic Uncertainty | Uncertainty in Z

Pose uncertainty reduction
Initial uncertainty is in XY translation



Scene | Image | Range Image | Pixelwise Mutual Information

- Informative areas are the slopped regions. (depends on initial uncertainty)
- Analogue to the aperture problem.

Conclusion

- Sensor planning at the sensor level for 3D scanners.
- Adapt sensing to context and task. Examples: Localization and mapping. Applicable to other tasks / modalities.
- Focused-information for range sensing - 50% reduction in required frames.
- Focused-information for pose estimation - shows the informative areas.

Contact Information

`http://people.csail.mit.edu/rosman/papers/cvpr16_active_scanner.pdf`
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