

3D Modeling Using STRUCTURE Sensor

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Jungwon Kang

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3D Scanning for Modeling

- **Modeling of Indoor Space, Object-of-Interest, and Many Other Things**



*source: https://youtu.be/IEeW_byzB8Y

Commercial 3D Scanners

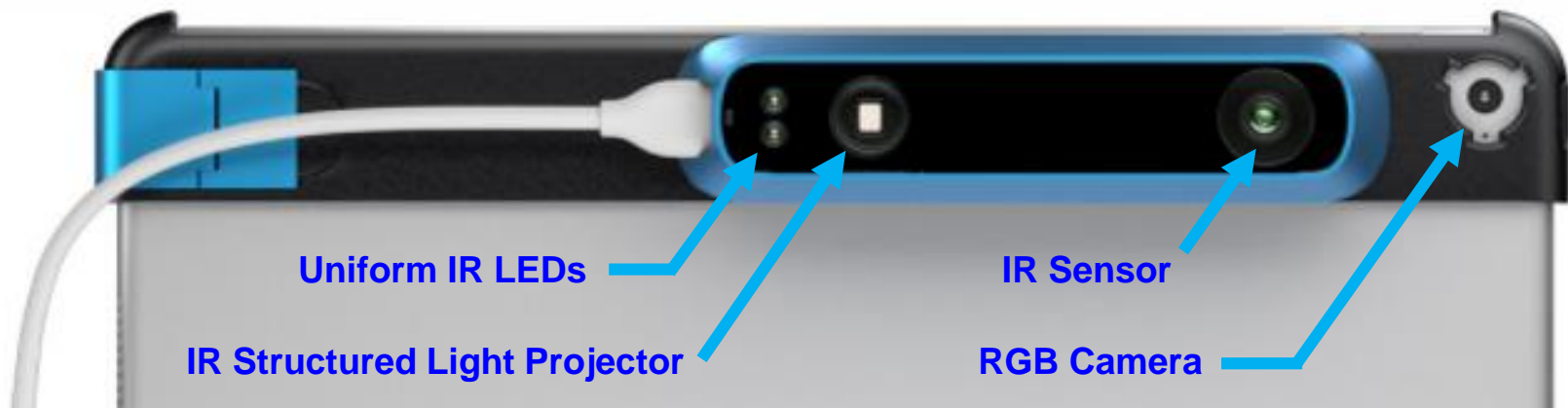
- **Many Commercial Ones, But Quite Expensive (for Personal Use)**



Matterport Pro2 3D Camera (MC250):
USD 3995 [Device] + USD 100/Month [Data Processing Service]

STRUCTURE Sensor (1/3)

- **STRUCTURE Sensor: A Consumer-Grade 3D Scanner**
 - Developed by [Occipital](#) Inc. in 2014
 - Small, lightweight IR-based 3D scanner
 - Provides RGB-D data (when combined with iPad RGB camera)
 - USD 379



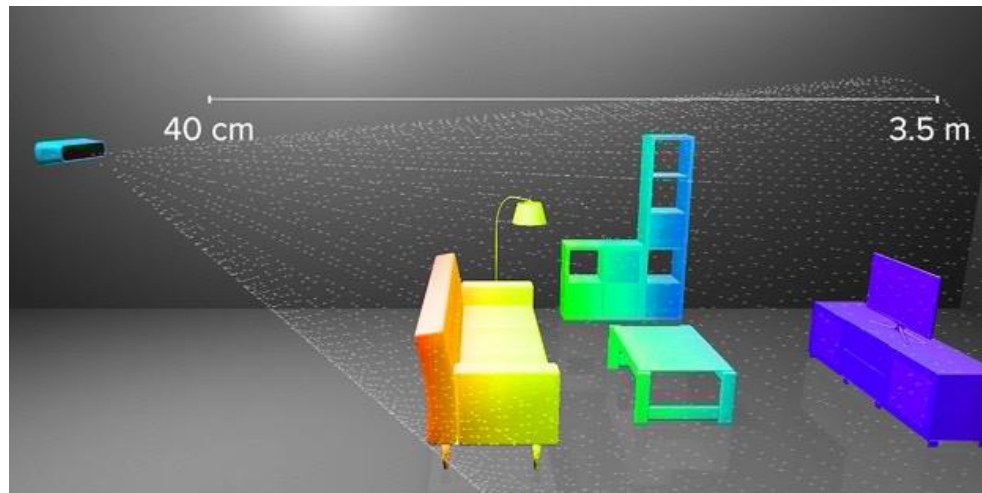
STRUCTURE Sensor (2/3)

■ Specification

Length x Width x Height	119.2 mm x 27.9 mm x 29 mm
Weight	99.2 grams
Sensing distance	40 cm ~ 3.5 m
Precision	1% of measured distance
Resolution	VGA(640 x 480) / QVGA (320 x 240)
Framerate	30 / 60 frames per second
Battery Life	3-4 hours of active sensing
Field of View	58° (Horizontal), 45° (Vertical)



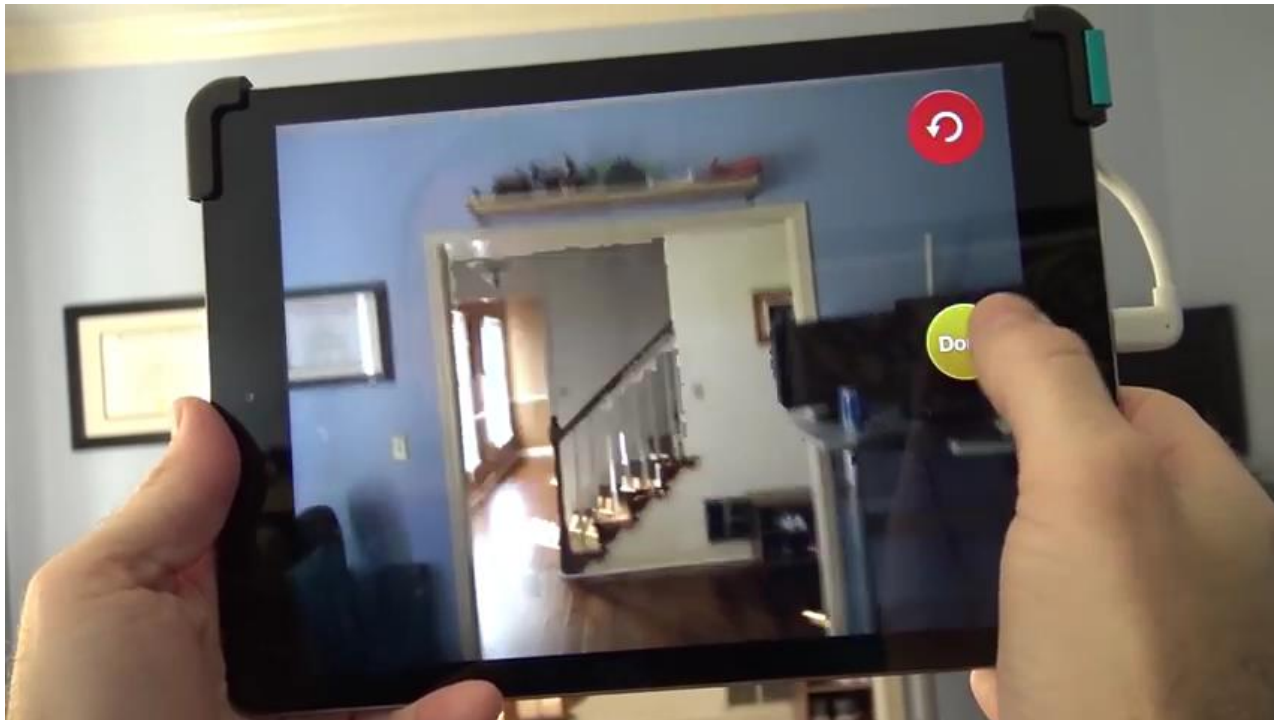
STRUCTURE sensor on a iPad



STRUCTURE Sensor (3/3)

■ What You Can Do Using STRUCTURE Sensor

- Modeling of indoor space (using *Room Capture* app), object-of-interest (using *Scanner* app)
- Augmented reality (using *Fetch* app)



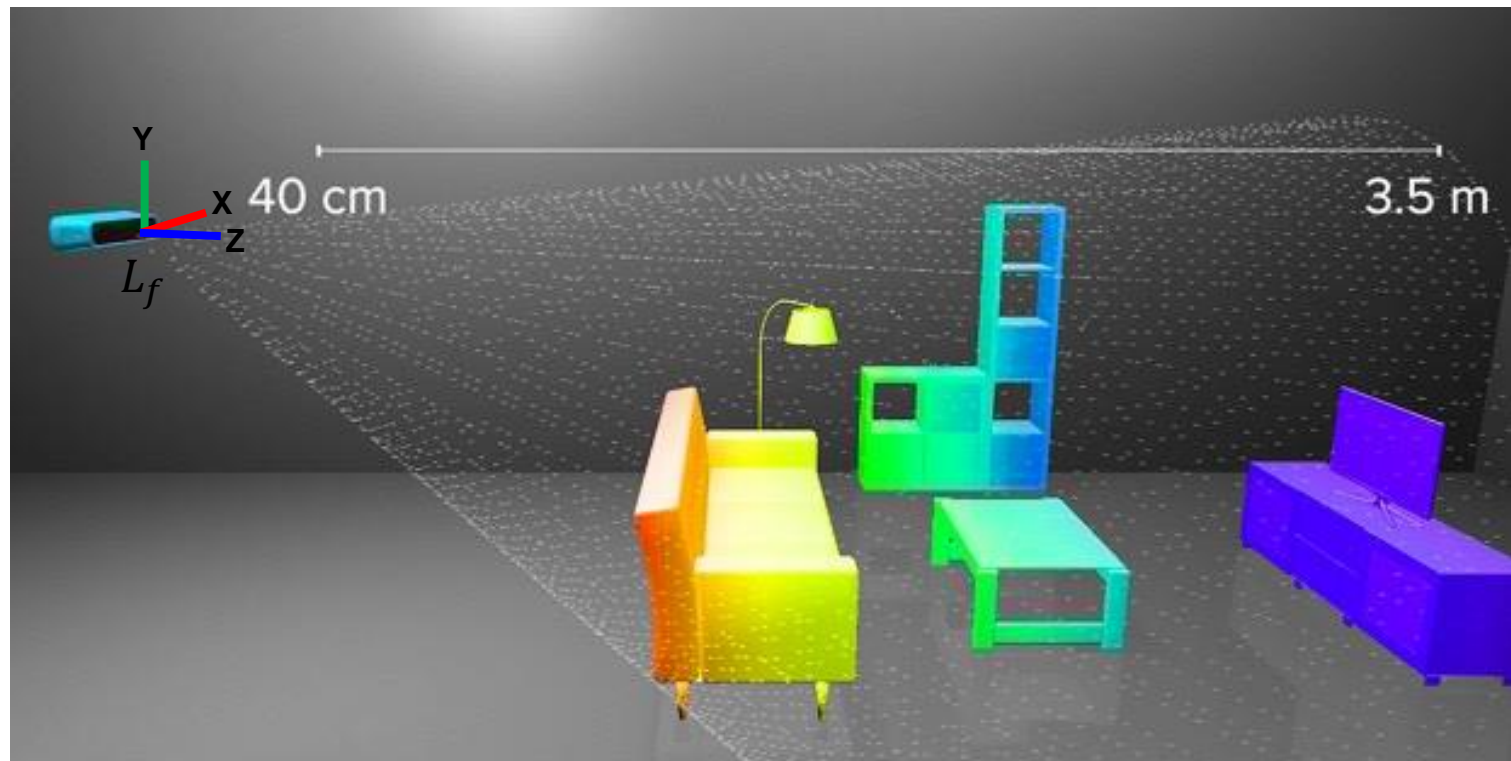
*source: <https://youtu.be/f7wTrLUERHE>, https://youtu.be/nFyT2q8f_i4

3D Modeling from Scanning (1/6)

▪ Point Cloud Generation (At a Certain Frame)

- Generation of a set of points wrt a local sensor coordinate at a certain frame

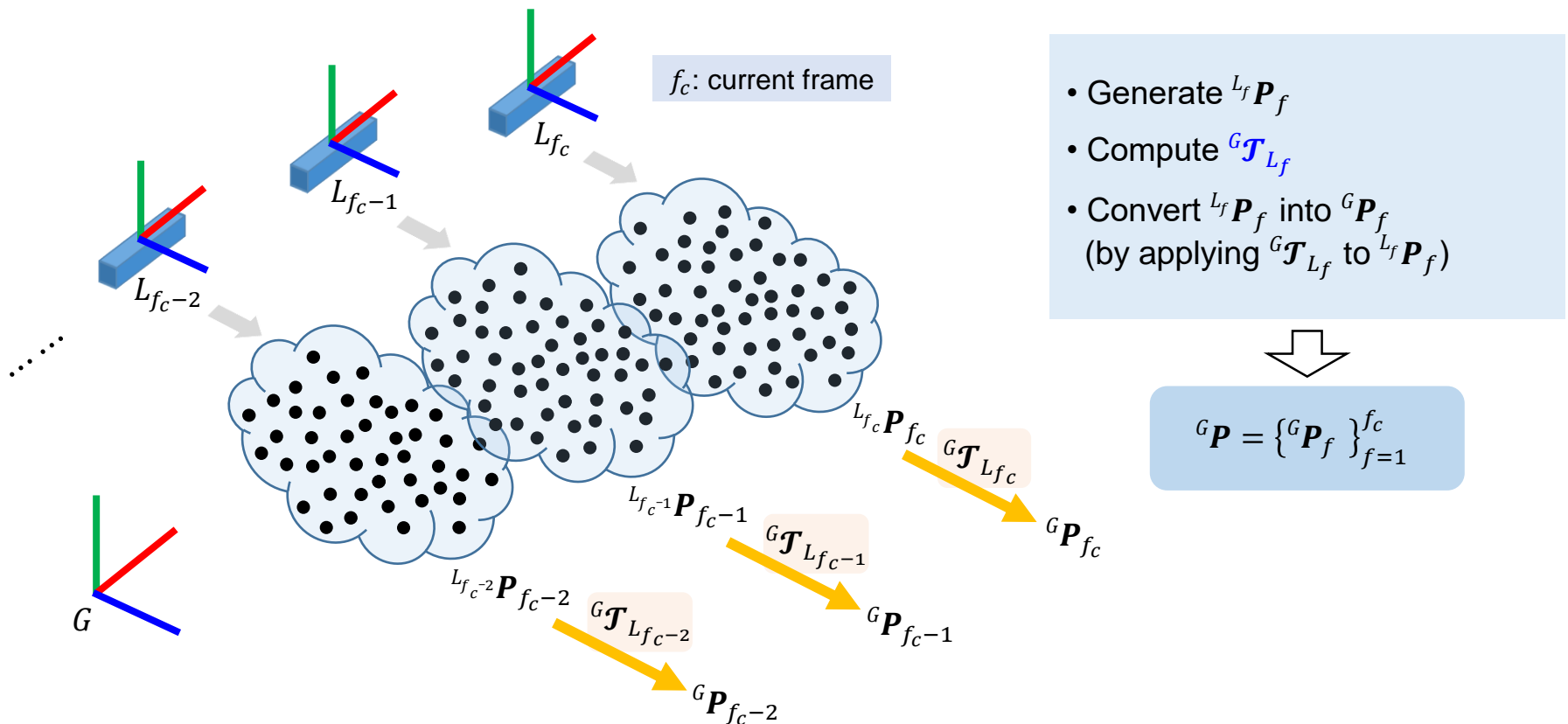
L_f : local sensor coordinate at frame f



3D Modeling from Scanning (2/6)

Integration of Point Cloud at Each Sensor Pose

- Formally, called **point cloud registration**
- Registering point clouds wrt a local sensor coordinate in a global coordinate

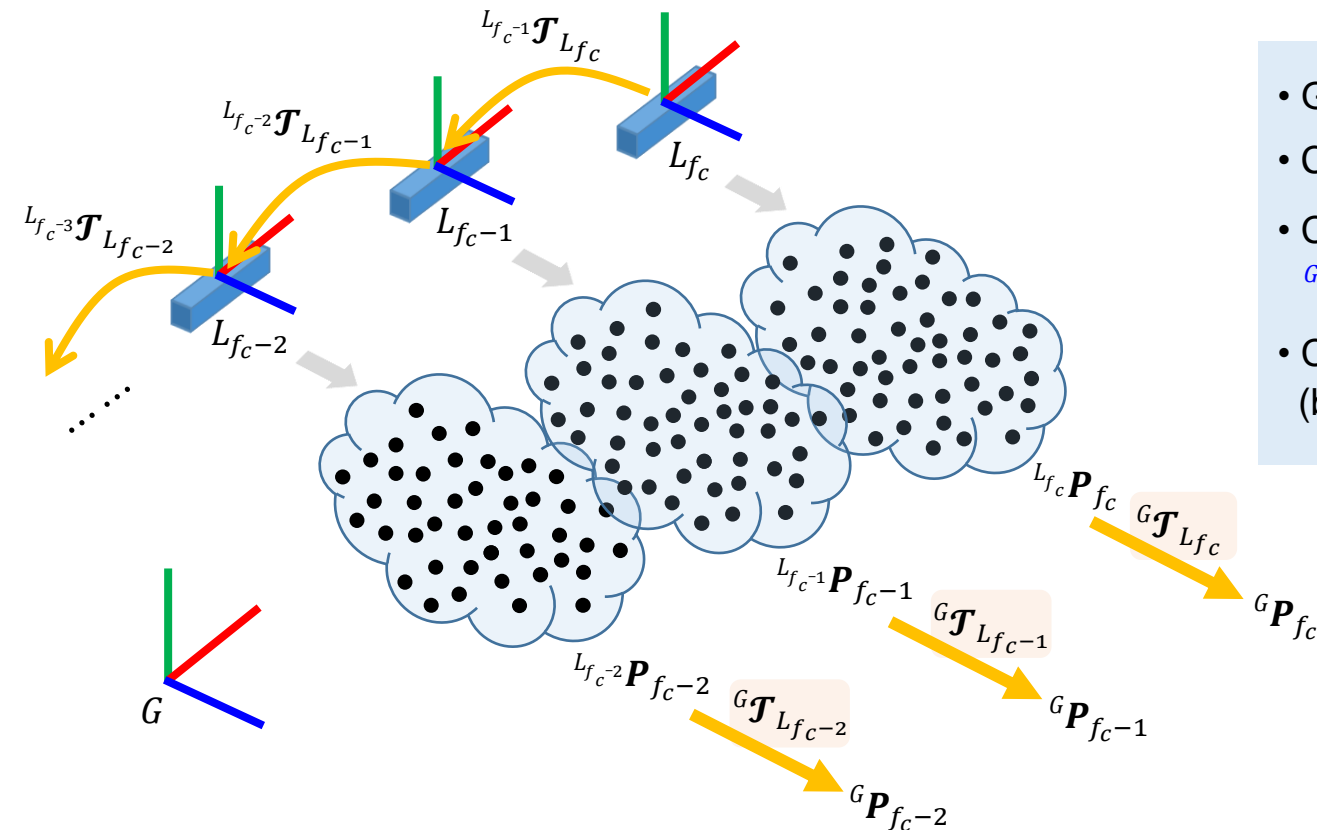


3D Modeling from Scanning (3/6)

Point Cloud Registration Based on Two Consecutive Frames

- Concatenation of relative sensor poses (obtained by ICP algorithm)
- Usually inaccurate due to accumulated error.

*ICP: Iterative Closest Point



- Generate $L_f P_f$
- Compute $L_{f-1} T_{L_f}$ using ICP
- Compute $G T_{L_f}$ from

$$G T_{L_f} = G T_{L_0} \dots L_{f-2} T_{L_{f-1}} L_{f-1} T_{L_f}$$
- Convert $L_f P_f$ into $G P_f$
 (by applying $G T_{L_f}$ to $L_f P_f$)

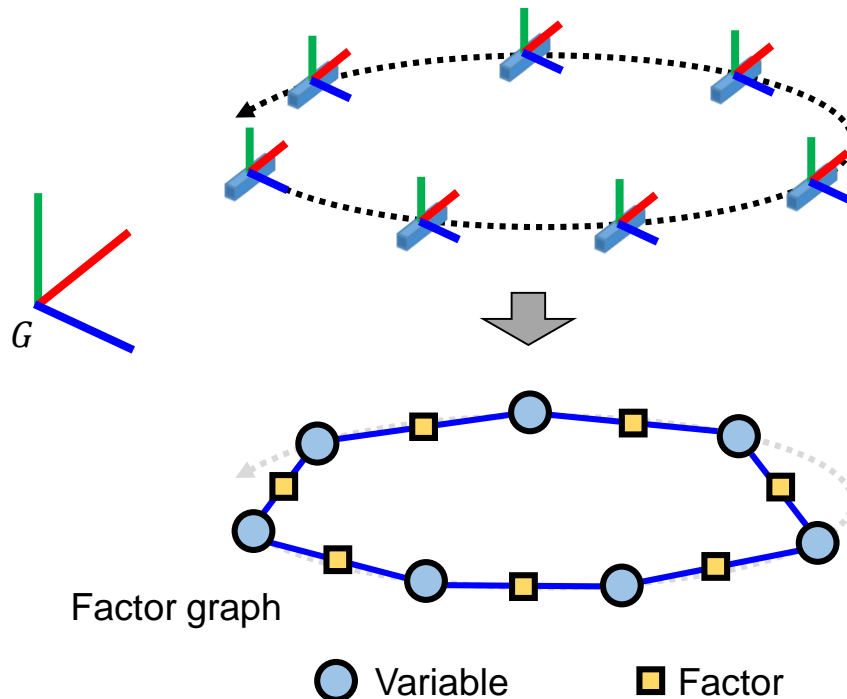


$$G P = \{ G P_f \}_{f=1}^{f_c}$$

3D Modeling from Scanning (4/6)

Point Cloud Registration Based on All Frame Adjustment

- Formally, called **pose graph optimization**
- Using a **factor graph** where the *variables* are sensor poses to be estimated, and the *factors* are relative pose measurements between sensor poses
 - ✓ Reduces the accumulated errors when a **loop closing** is detected.



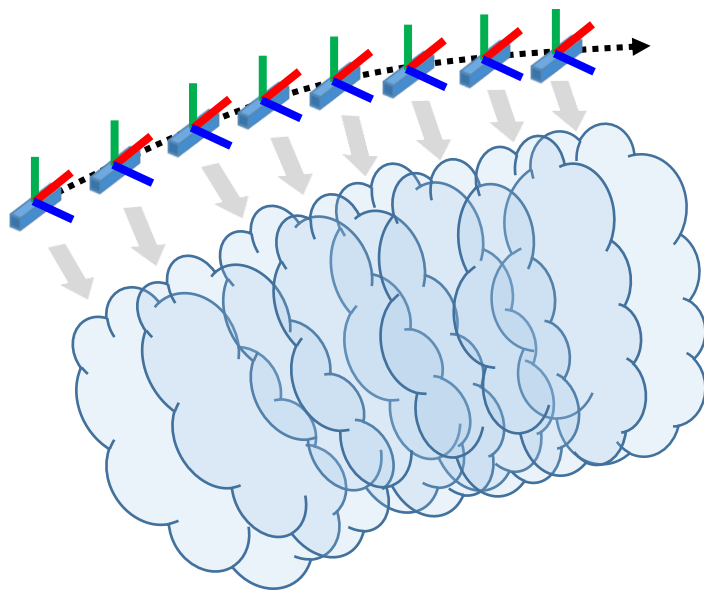
- Generate ${}^{L_f}\mathbf{P}_f$
- Compute ${}^{L_{f-1}}\mathbf{T}_{L_f}$ using ICP
- Compute ${}^G\mathbf{T}_{L_f}$ by solving

$$\mathcal{X}^* = \arg \min_{\mathcal{X}} \frac{1}{2} \sum_f \|h_f(\chi_f) - z_f\|_{\Sigma}^2$$
 where $\mathcal{X}^* = \left\{ {}^W\mathbf{T}_{L_f} \right\}_{f=1}^{f_c}$, $z_f = {}^{L_{f-1}}\mathbf{T}_{L_f}$
- Convert ${}^{L_f}\mathbf{P}_f$ into ${}^G\mathbf{P}_f$ (by applying ${}^G\mathbf{T}_{L_f}$ to ${}^{L_f}\mathbf{P}_f$)

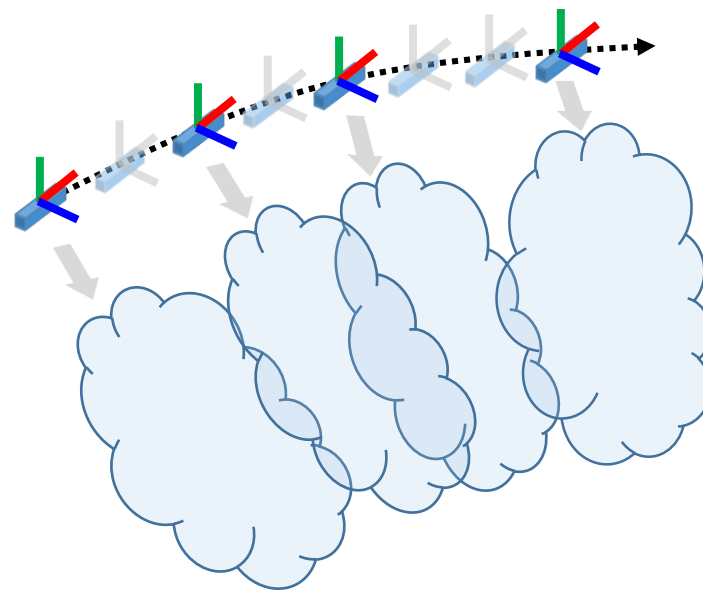
$${}^G\mathbf{P} = \left\{ {}^G\mathbf{P}_f \right\}_{f=1}^{f_c}$$

3D Modeling from Scanning (5/6)

- Using **Keyframes** for Pose Graph Optimization
 - Selecting informative frames as *keyframes* for efficient operation with low data redundancy
 - Using a factor graph for sensor poses at keyframes



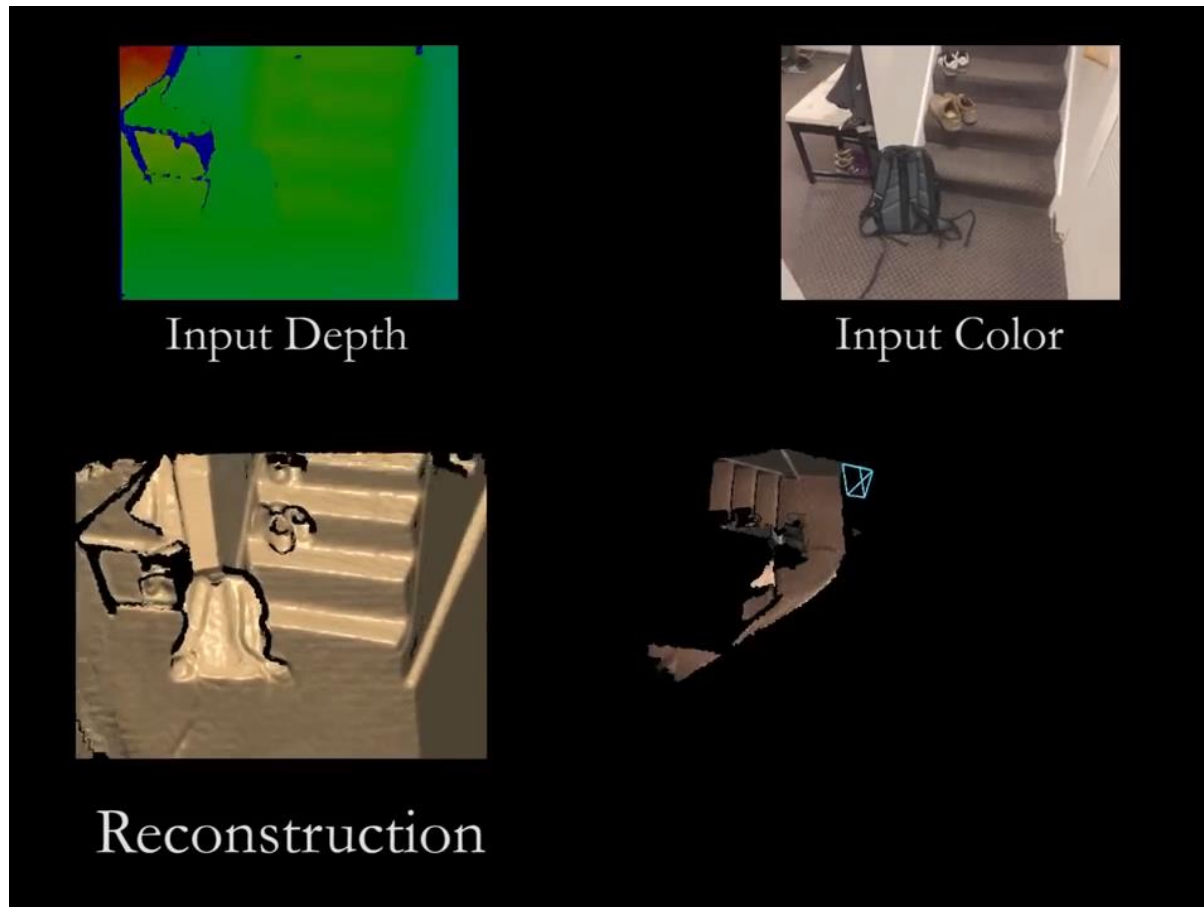
Using all frames



Using keyframes

3D Modeling from Scanning (6/6)

- **Point Cloud Registration Based on All Frame Adjustment**



[A. Dai, 2017]

*source: <https://youtu.be/kelirXrRb1k>

Conclusion

▪ **STRUCTURE Sensor**

- A consumer-grade 3D scanner (for personal use)
- Provides several apps for modeling of indoor space, object-of-interest, and augmented reality.

▪ **3D Modeling from Scanning**

- Keywords: point cloud registration / ICP / pose graph optimization / keyframes

▪ **Some Notes on Your Practice**

- See how certain materials affect scanning.
 - ✓ Tip: Try scanning a mirror or a glass.
- See when generated 3D model is inaccurate.
 - ✓ Tip: In order to enhance the quality of 3D model, please simplify your own motion while scanning.