CNN-BASED INDOOR OCCUPANT LOCALIZATION VIA ACTIVE SCENE ILLUMINATION

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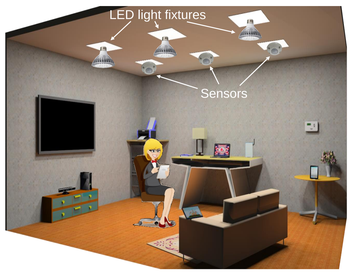
Motivation

- **Smart rooms of the future**:



- Energy savings
- Productivity gains
- Health benefits

- **Needed**: indoor localization

Wearable devices: intrusive

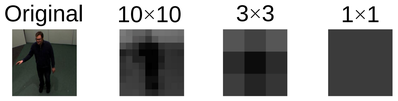
Cameras: privacy concerns

- **Goal**: non-intrusive, privacy-preserving indoor localization

Localization with Light

- **Camera:**  Privacy?
- **Extremely Low Resolution Sensor:**

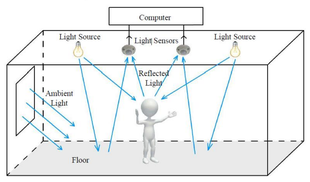
Original 10×10 3×3 1×1



Performance?

Full resolution ⟶ single-pixel

- **Network of Single-Pixel Sensors:**



Robustness to illumination changes?

- **Network of Single-Pixel Sensors + Active Illumination:**
  - Modulate light
  - Measure changes in sensor outputs
  - Localize

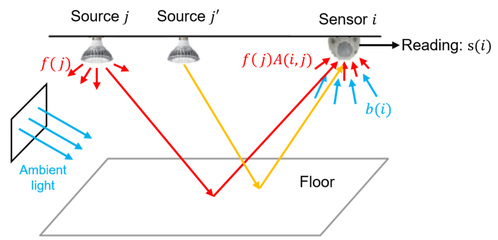
Methods to Date: Model-based (Zhao *et. al* 2018)

Contributions

- Data-driven method using a small CNN
- Validation: simulation and real-world testbed

Active Scene Illumination

1. **Modulate** the intensity of light fixtures
2. **Measure** sensor responses



3. **Compute** light transport matrix $\boldsymbol{A}$

$$\begin{bmatrix} s(1) \\ \vdots \\ s(i) \\ \vdots \\ s(N_s) \end{bmatrix} = \begin{bmatrix} b(1) \\ \vdots \\ b(N_s) \end{bmatrix} + \begin{bmatrix} A(1,1) & \cdots & \cdots \\ \vdots & A(i,j) & \vdots \\ \cdots & \cdots & A(N_s,N_f) \end{bmatrix} \begin{bmatrix} f(1) \\ \vdots \\ f(j) \\ \vdots \\ f(N_f) \end{bmatrix}$$

$$\boldsymbol{s} = \boldsymbol{b} + \boldsymbol{A} \cdot \boldsymbol{f}$$

$$\Delta\boldsymbol{s} = \boldsymbol{A} \cdot \Delta\boldsymbol{f}$$

4. **Compute** change $\Delta\boldsymbol{A} = \boldsymbol{A}_{empty} - \boldsymbol{A}_{occupied}$

5. **Estimate** occupant's location (x, y) from $\Delta\boldsymbol{A}$

CNN-Based Solution

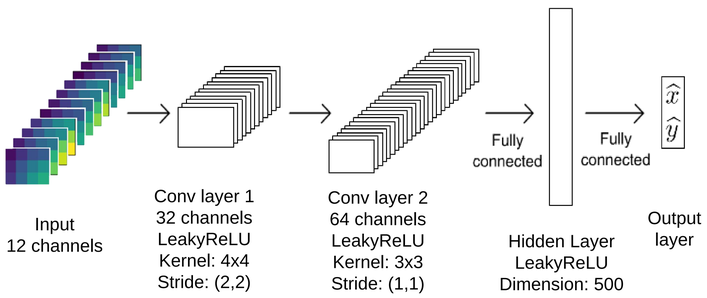
Goal: learn mapping $\Delta\boldsymbol{A}$ → (x, y) using training data

Input 3D tensor:

1 channel = 12 sensor measurements from **single-fixture light**

0	3	6	9
1	4	7	10
2	5	8	11

Preserves spatial coherence

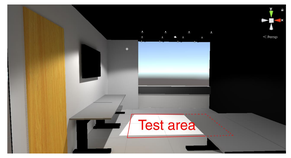


Experimental Results

Private Scenario
Example: home, small office
All users appear in training and test sets

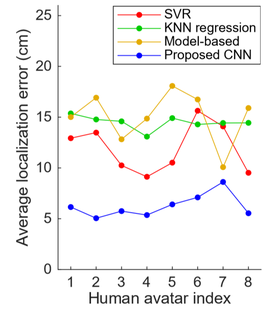
Public Scenario
Example: mall, theater
Test set contains unseen users

Unity3D Simulation

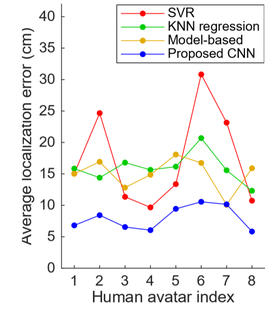


Rom simulated in Unity3D

8 human avatars

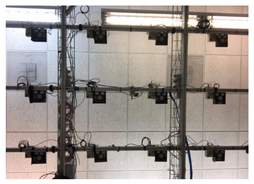


Private scenario

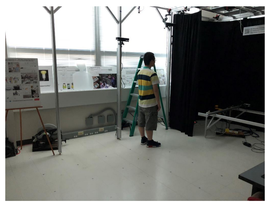


Public scenario

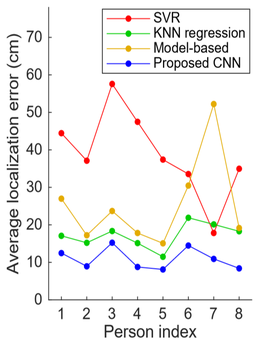
Real Testbed



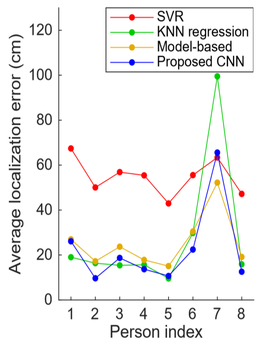
Overhead-mounted light fixtures and sensors



Occupant in real testbed



Private scenario



Public scenario

Conclusions

- CNN-based approach outperforms both model-based and traditional data-driven methods
- Shallow network sufficient due to low data dimensionality
- New approach requires no knowledge of room geometry, which is cumbersome to capture

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