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People Tracking for Enabling Human-Robot Interaction in Large Public Spaces

- This work was largely done at ATR

  Intelligent Robotics and Communication Laboratory

  Kyoto, Japan

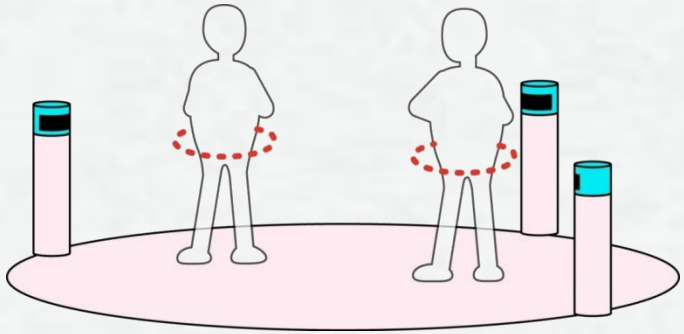
  (1/2011 - 9/2016)

Motivation

- Motivation: bring social service robots into our everyday environments
- However, robots still have limited sensing abilities
- Solution: use sensors installed in the environment

Our previous solution

- Using multiple laser range finders
- Stable and quite accurate tracking can be achieved
- Issues:
  - sensitive to occlusion
  - only 2D position information (no height, orientation, etc.)



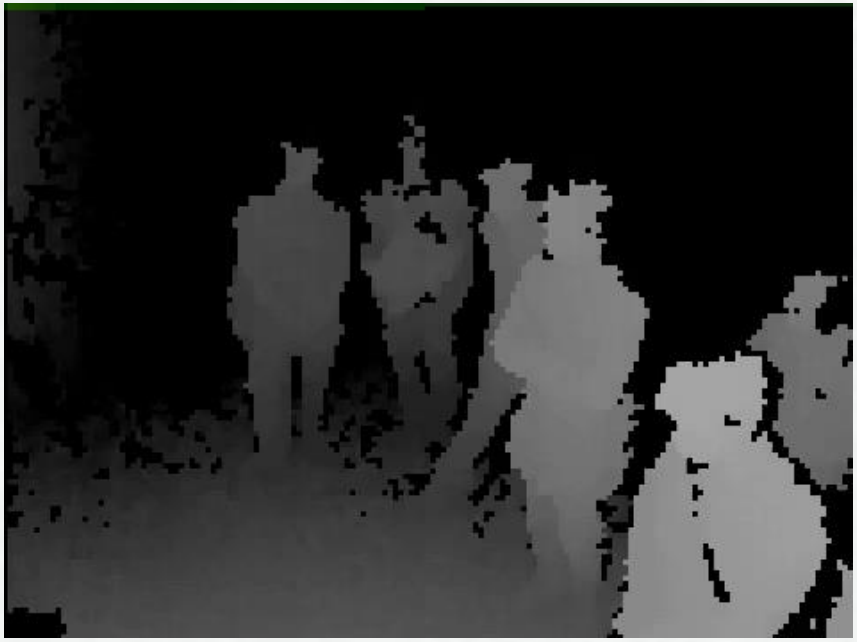
3D range sensors

- Measure the distance to the objects – 3D shape of the objects can be obtained

Sensing principle	Scan area	Robustness to noise, interference	Price range	Examples
Stereo camera	Few meters	××	Mid	BumbleBee
Projection	Few meters	×	Low	Kinect, Asus XTION
TOF camera	Few meters	×	Mid	D-IMager, SwissRanger
Rotating 3D laser scanner	Tens of meters	○	High	Velodyne

Examples of sensor outputs

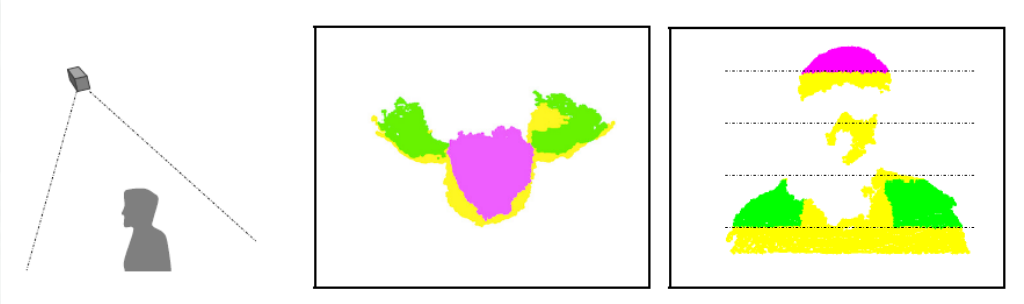
Microsoft Kinect
(experimental room)

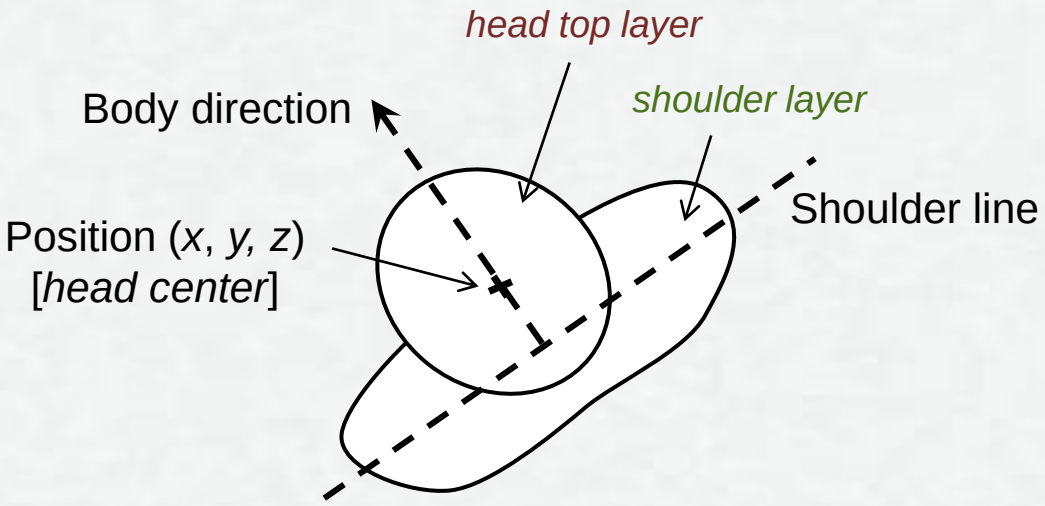


Panasonic D-IMager
(public space)

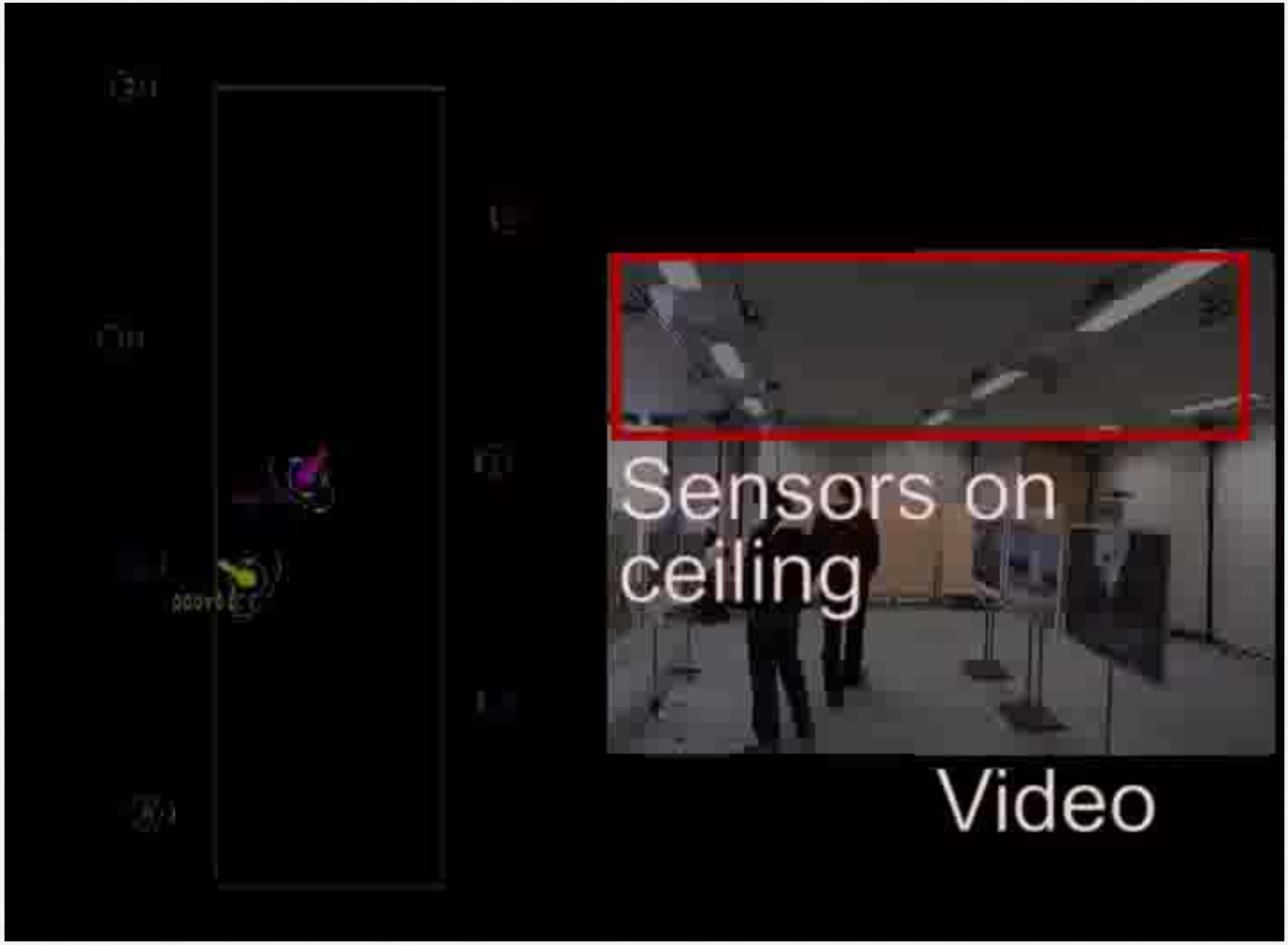
Basic pose estimation method

- Simple heuristic:
  - Division into layers and extraction of features
  - Robust to noise, missing data and low resolution
- Continuous tracking using PF





Tracking in a room



Evaluation (room tracking)

- Motion tracker data as ground truth and comparison with LRF (using CLEAR MOT metrics*)

Number of persons :		**2**	**4**	**8**
LRF	Precision [mm]	95.17	116.79	124.79
	Accuracy [%]	99.83	99.55	97.76
3D	Precision [mm]	74.48	82.50	73.60
	Accuracy [%]	99.94	99.97	99.88

* from B. Keni, S. Rainer, EURASIP Journal on Image and Video Processing, vol. 2008

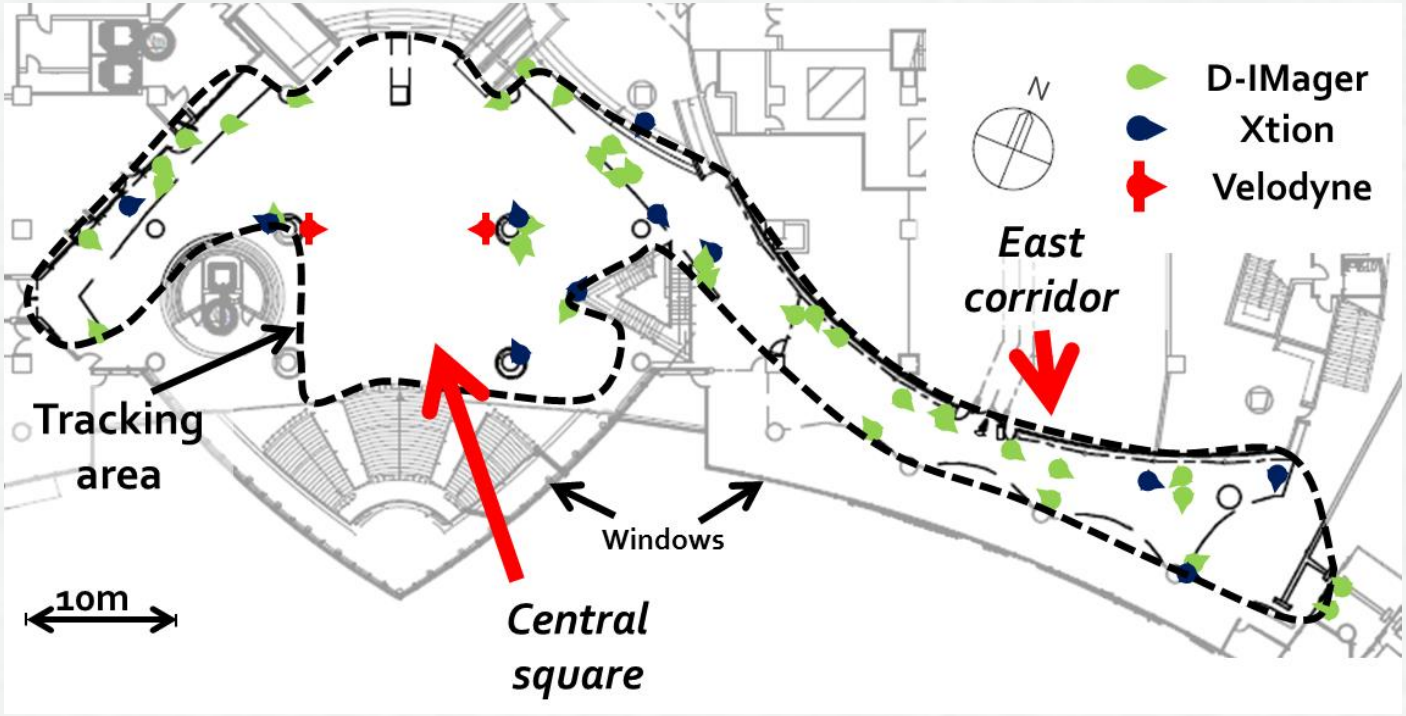
Installation in shopping mall [2012]

- Combination of different sensors

47 range sensors:
4 m above ground,
on ceiling and
pillars

2 Velodyne
rotating laser
scanners:
8 m height –
for covering
the square

ATC sensing environment



- Corridors / square – 900m^2 area
- Simultaneous tracking of up to 200 persons

Tracking in ATC

Evaluation (ATC)

- Only accuracy (no ground truth)

Day of week:	Weekday	Weekend	Combined
Accuracy [%]	98.63	93.21	94.47

→ Comparable to state of the art RGB camera based tracking, while being robust to environment and lighting changes

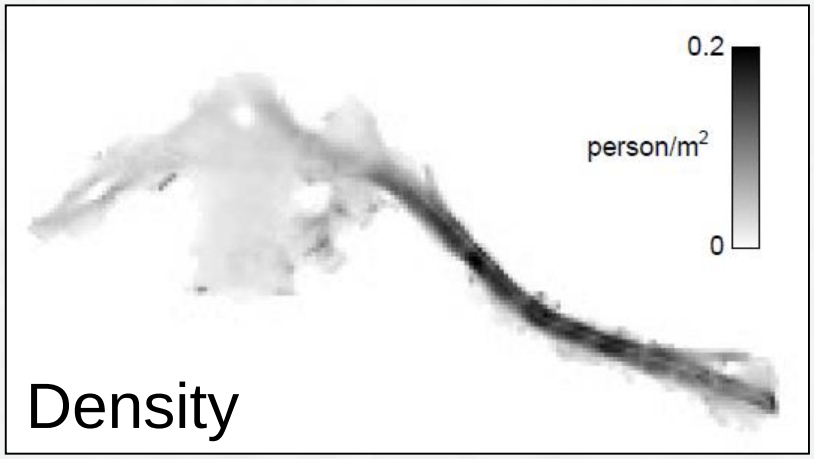
D. Brščić, T. Kanda, T. Ikeda, T. Miyashita, *Person tracking in large public spaces using 3D range sensors*, IEEE Transactions on Human-Machine Systems, 43 (6), 2013

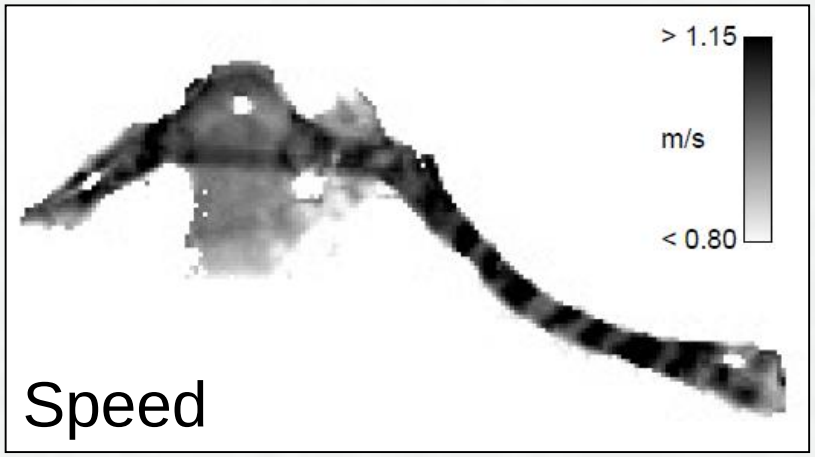
Benefits

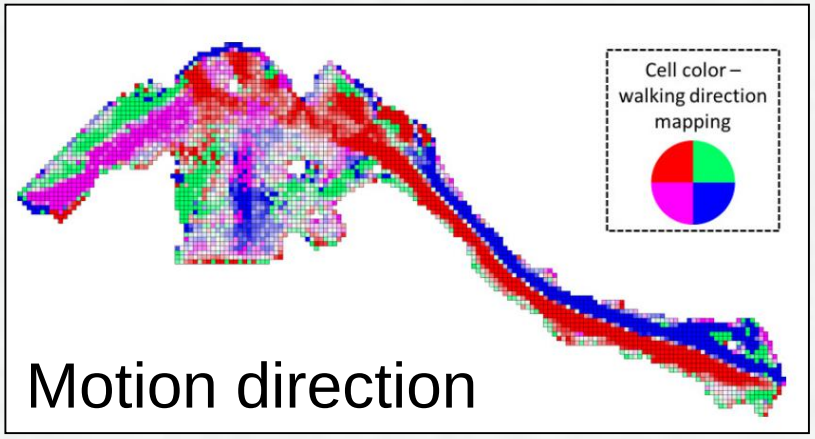
- Large area continuous real-time tracking
- Collection of statistics and modelling people’s behavior

- Enabled us to do experiments in the real world which were previously difficult

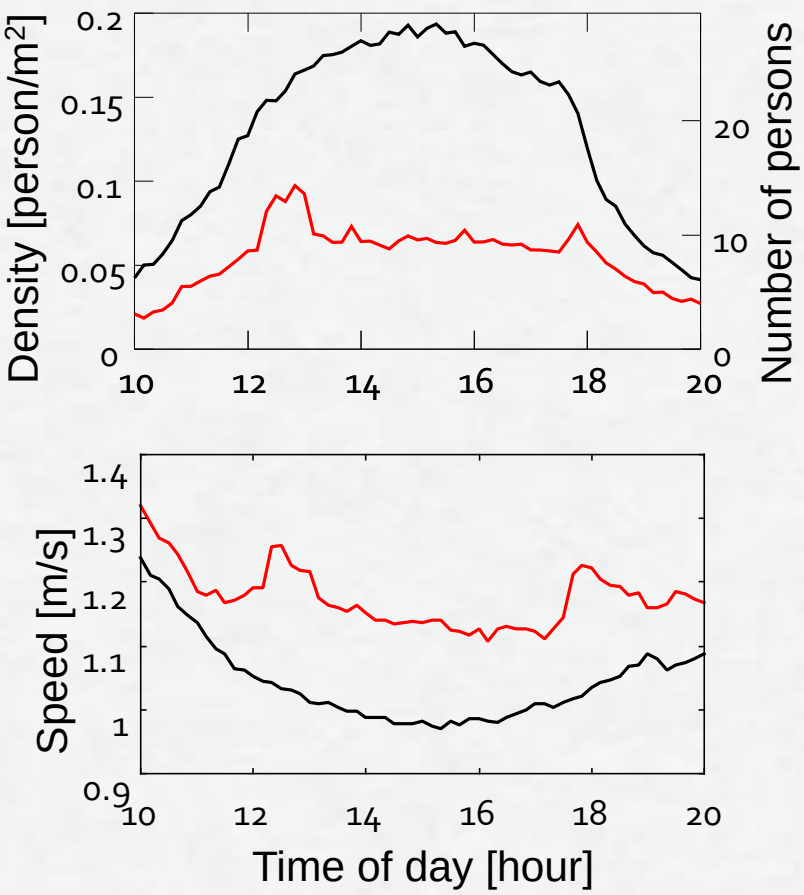
Statistic – usage of space







Statistic – changes during the day



Example: corridor data

- Much more persons on weekend than during the week + walking slower
- Workers rush-hours on weekdays

D. Brščić, T. Kanda, *Changes in usage of an indoor public space: analysis of one year of person tracking*, IEEE Transactions on Human-Machine Systems, Vol. 45, No. 2, pp. 228-237, 2015

Pedestrian behavior

- Also microscopic behavior of pedestrians:
  - Improved social-force model of pedestrian movement
  - Analysis of pedestrian groups and recognition
  - Effects of density, gender, age, etc. on group formation

F. Zanlungo, D. Brščić and T. Kanda, *Spatial-size scaling of pedestrian groups under growing density conditions*, Physical Review E 91.6, 2015, and other works of F. Zanlungo

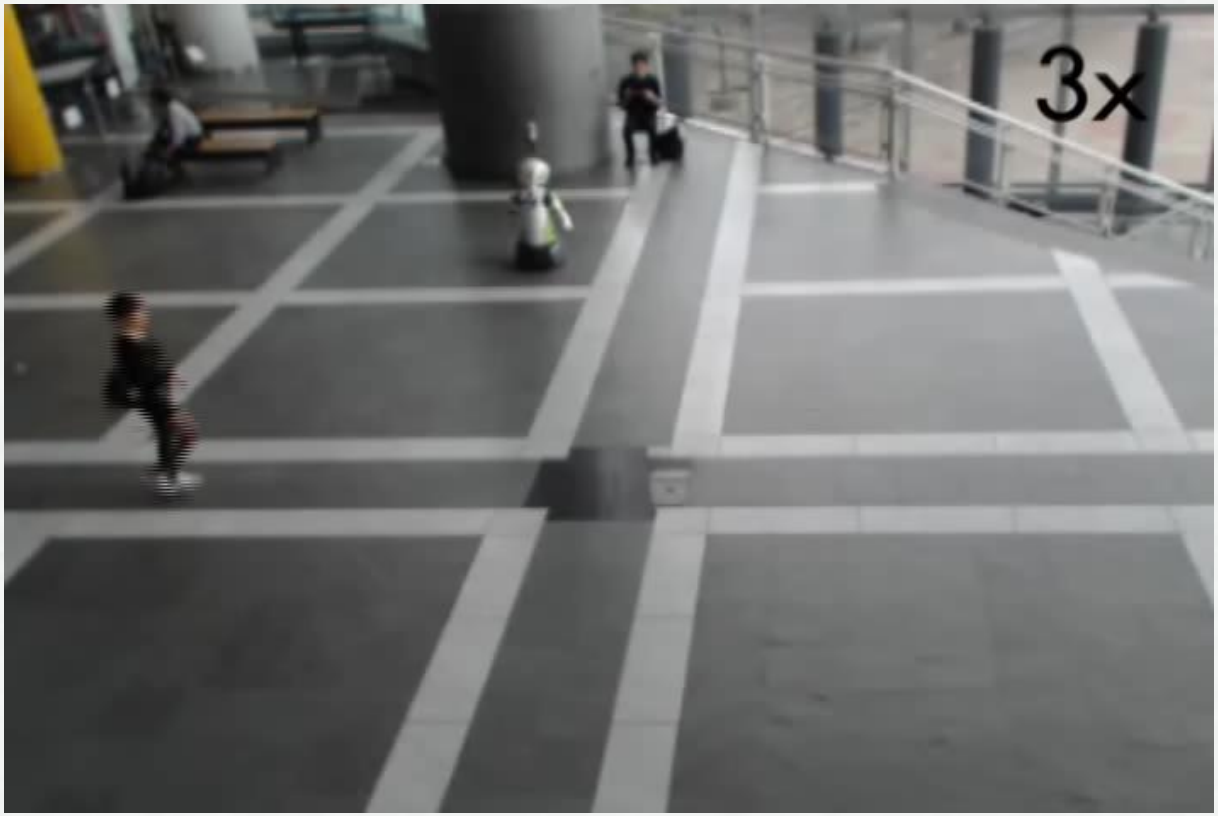
Human-robot interaction

Distribution of flyers:

C. Shi, M. Shiomi, C. Smith, T. Kanda, H. Ishiguro, *A model of distributional handing interaction for a mobile robot*, Robotics: Science and Systems Conference (RSS), pp. 24-28, 2013

Human-robot interaction

Approaching people in need of information:



D. Brščić, T. Ikeda, T. Kanda, *Do you need help? A robot providing information to people who behave atypically*, IEEE Transactions on Robotics, Vol. 33, No. 2, pp. 500-506, 2017

Human-robot interaction

- ASIMO as shopkeeper (Miraikan, Oct. 2013)

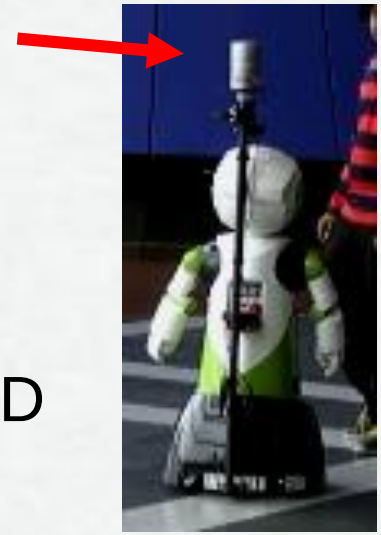
Issues

- Requirement for large and expensive installation
  - Low mobility
  - Limitation where and when can be used

→ Use onboard sensors instead

Onboard sensing

- Velodyne HDL-32E



- Sensing:
  - map built beforehand (using Slam6D package)
  - particle filter based 3D localization
  - tracking of all objects that are not in the map

Onboard sensing