Water Flow Detection in a Handwashing Task

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Toronto Rehab
Everything Humanly Possible

Outline

- Motivation
- Background
- Problem Definition
- Water Detection
  - Audio Processing
  - Video Processing
  - Classification
- Future Work

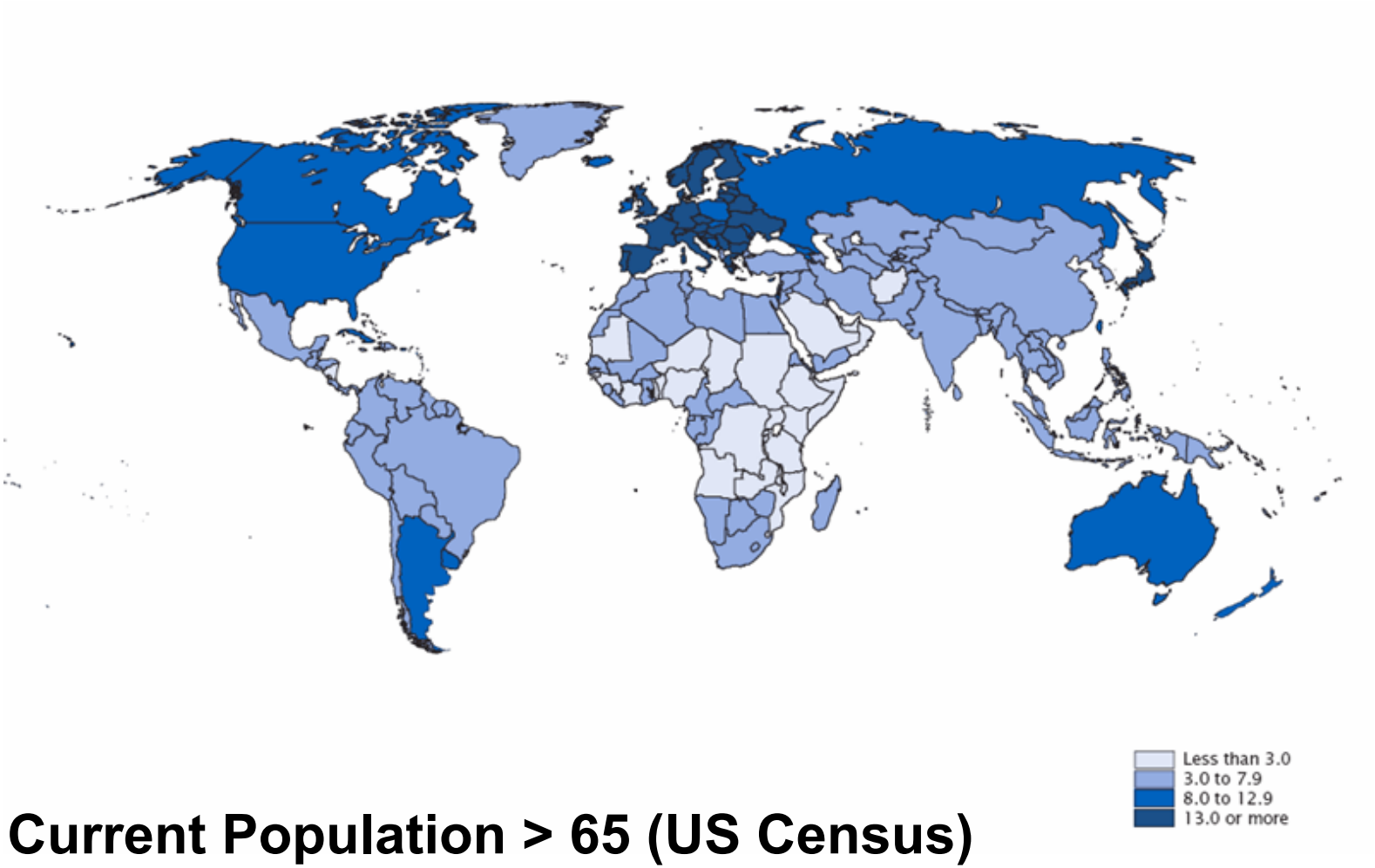
Problem Definition (Sneak Preview!)

- Water Detection

  Detect the flow of water in a bathroom sink

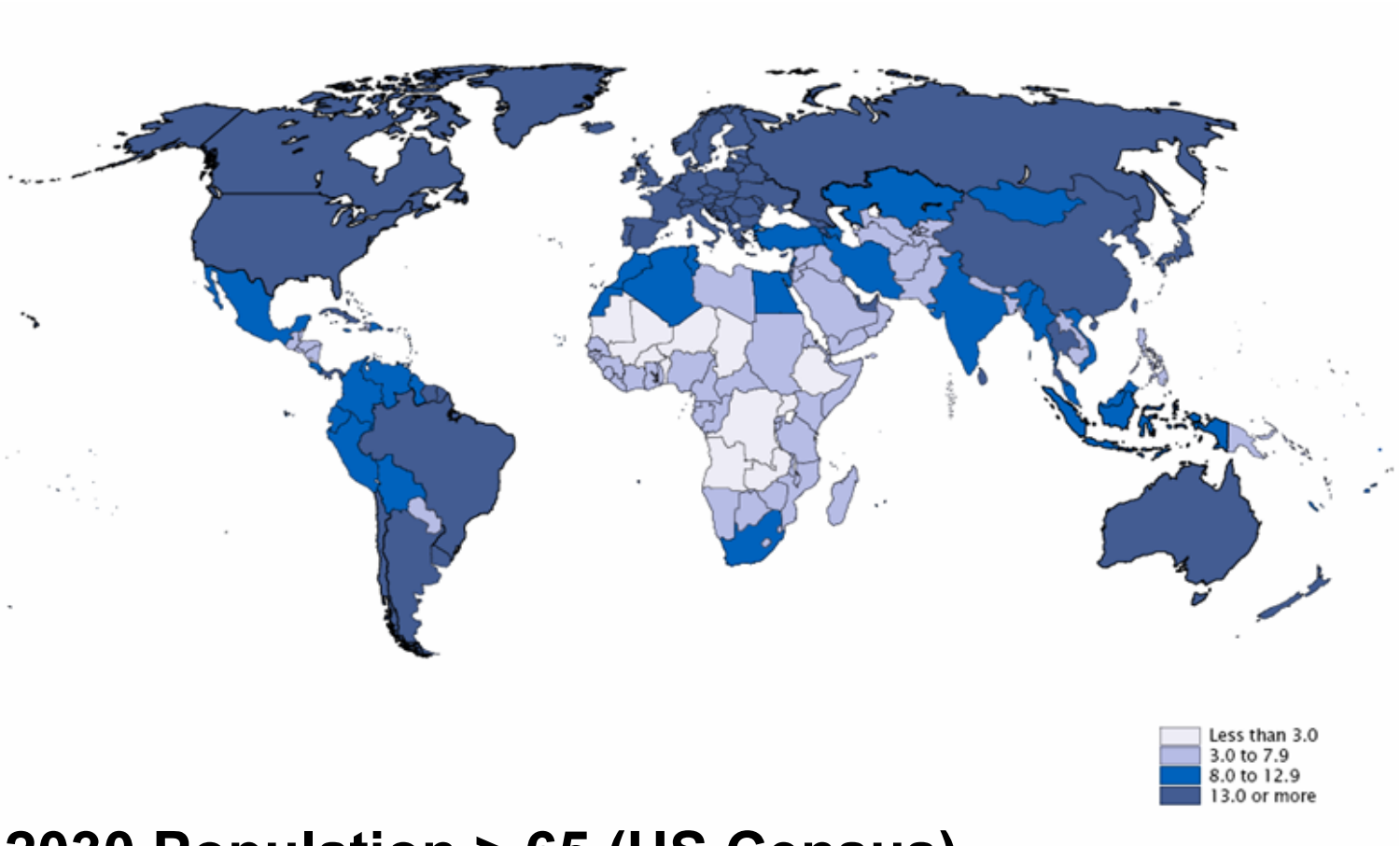
  - Video
  - Audio

Motivation (Changing Demographics)



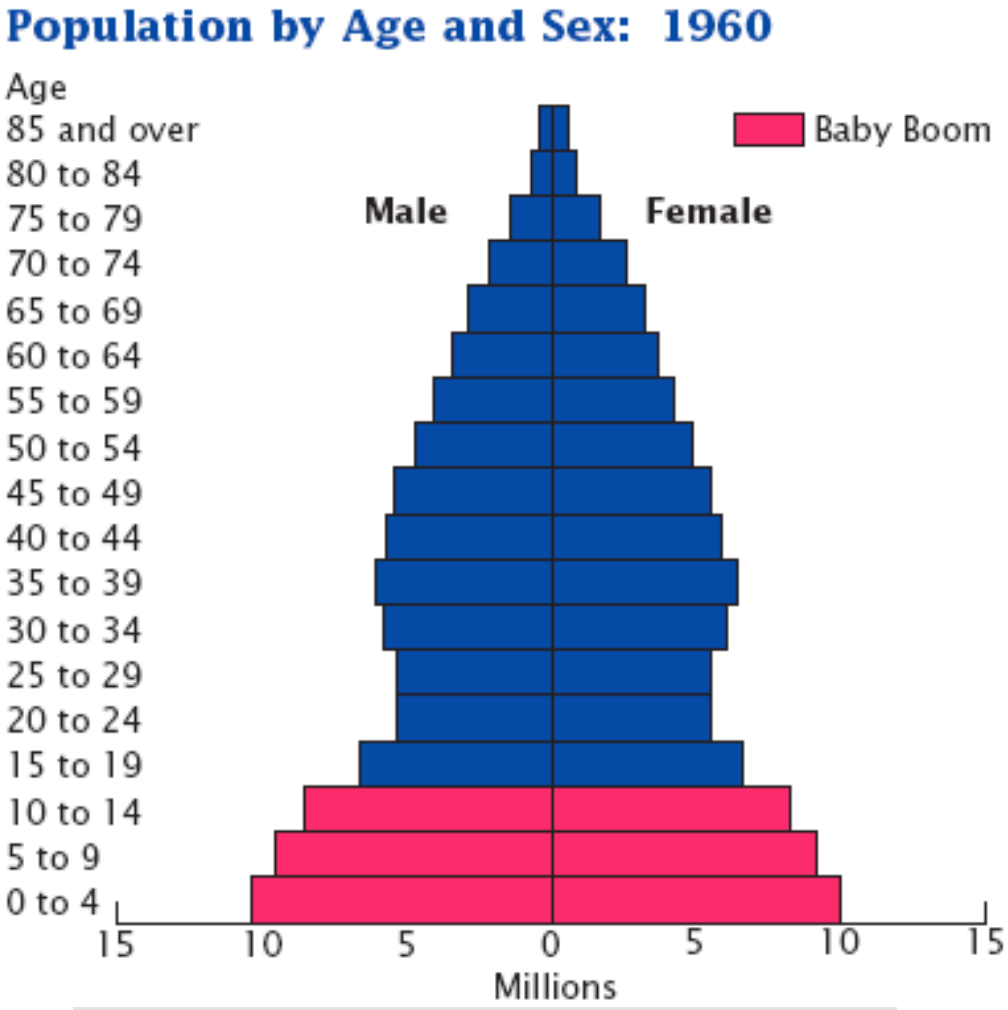
Current Population > 65 (US Census)

Motivation (Changing Demographics)



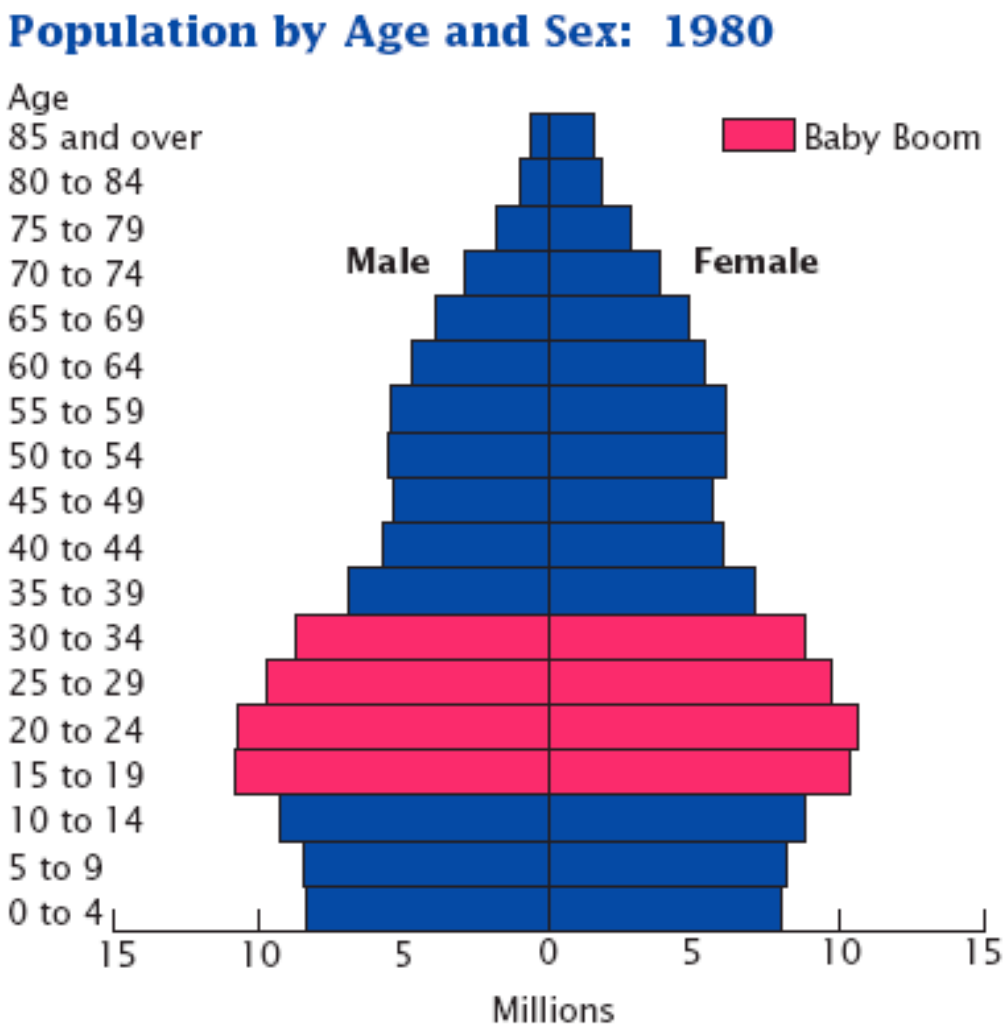
2030 Population > 65 (US Census)

Motivation (Changing Demographics)



US Census Dept, 2005)

Motivation (Changing Demographics)



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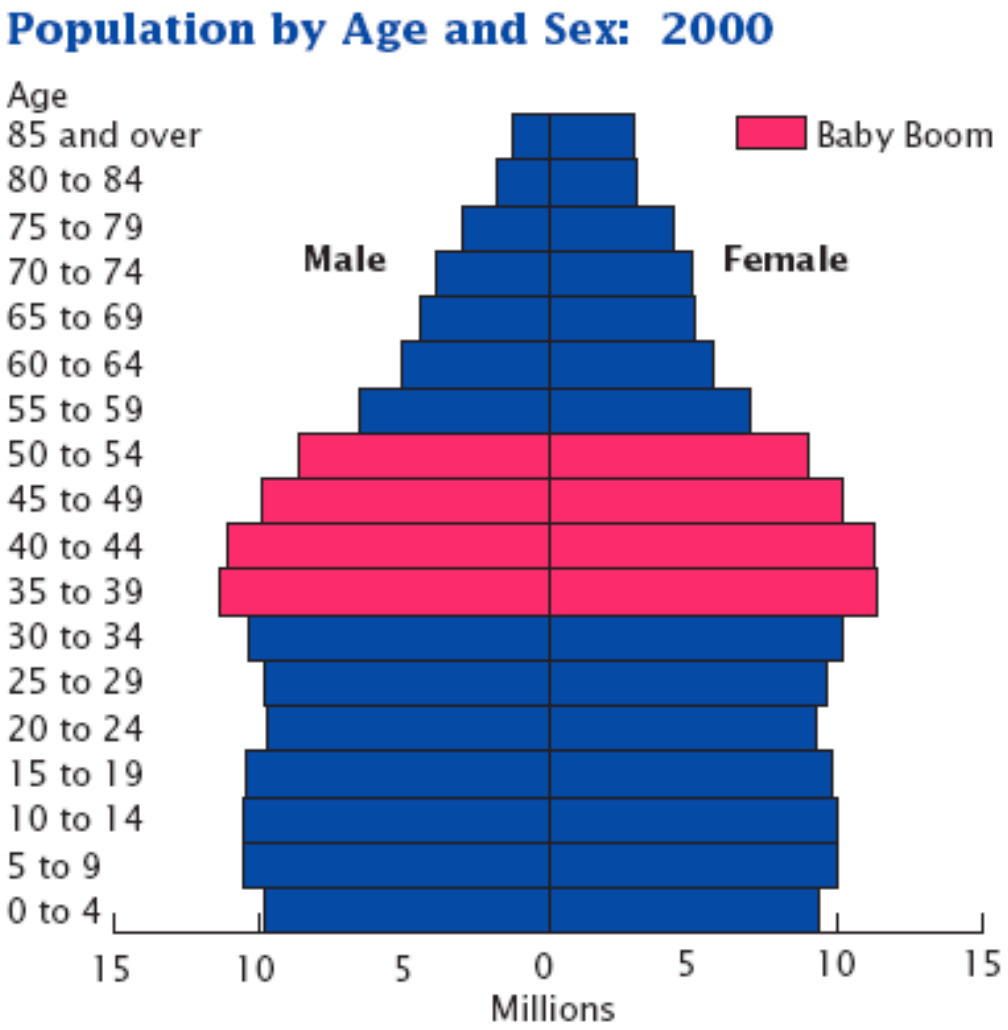

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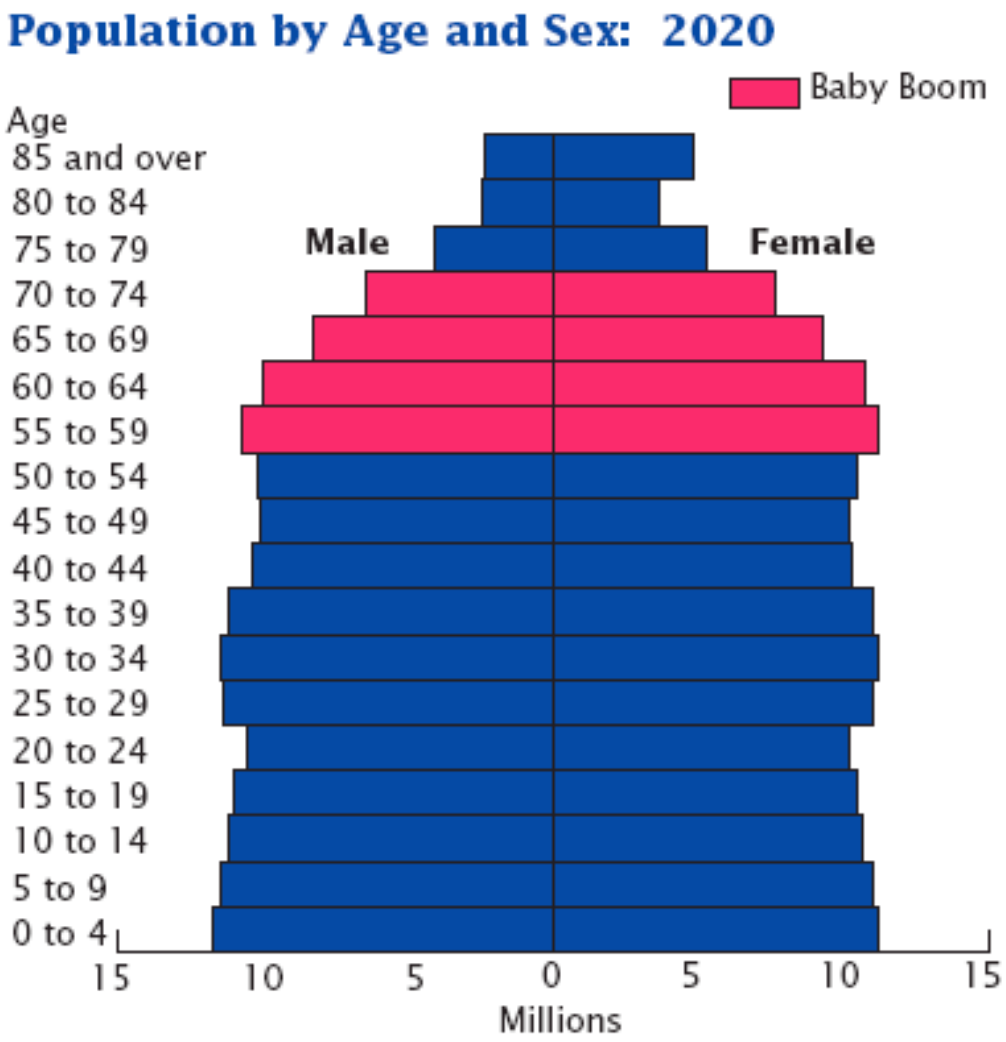

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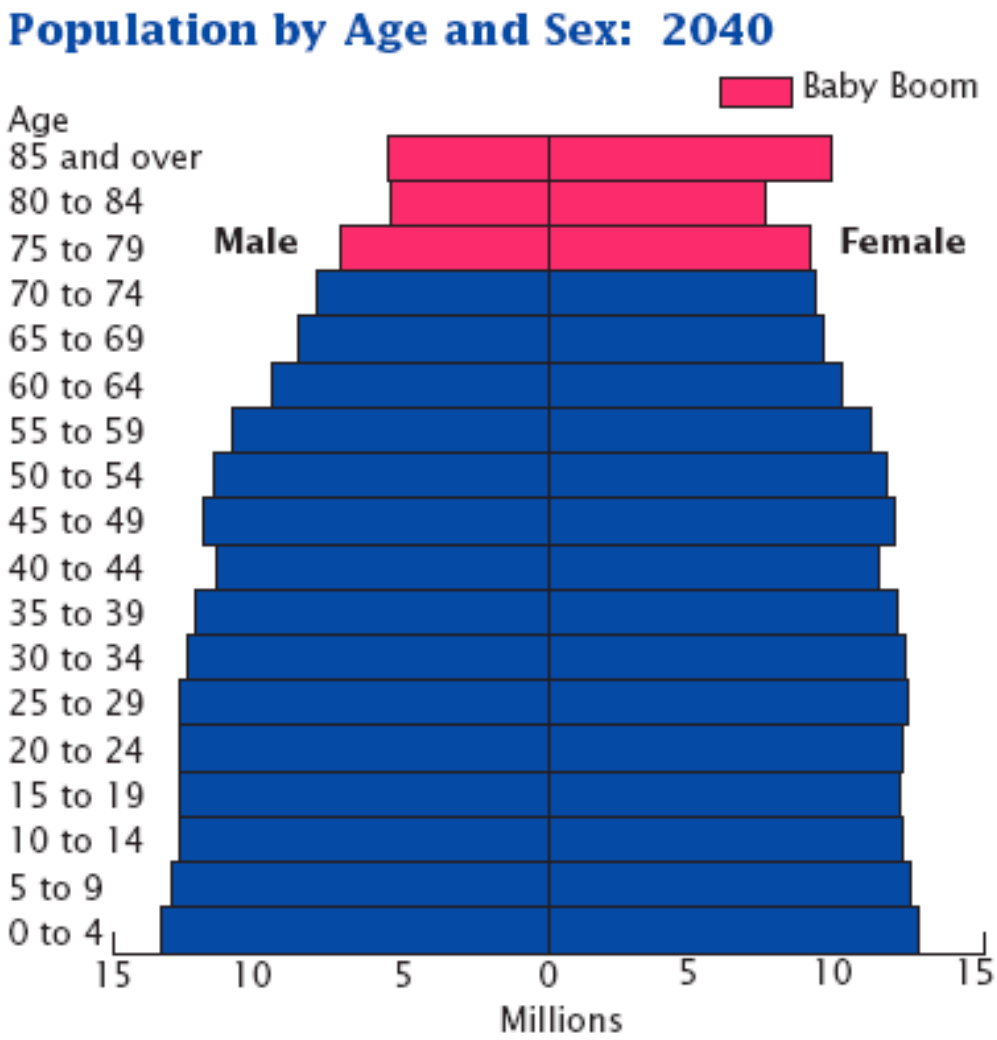


US Census Dept, 2005)

Motivation (Age Related Ailments)

 Number of older adults

 Diseases and impairments with age

 Number of caregivers

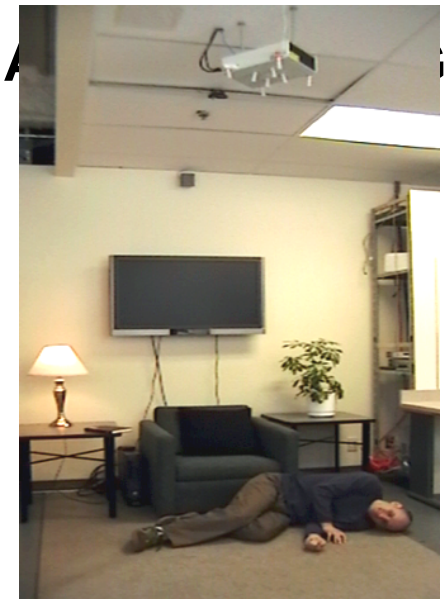
 Workload and burden / Cost

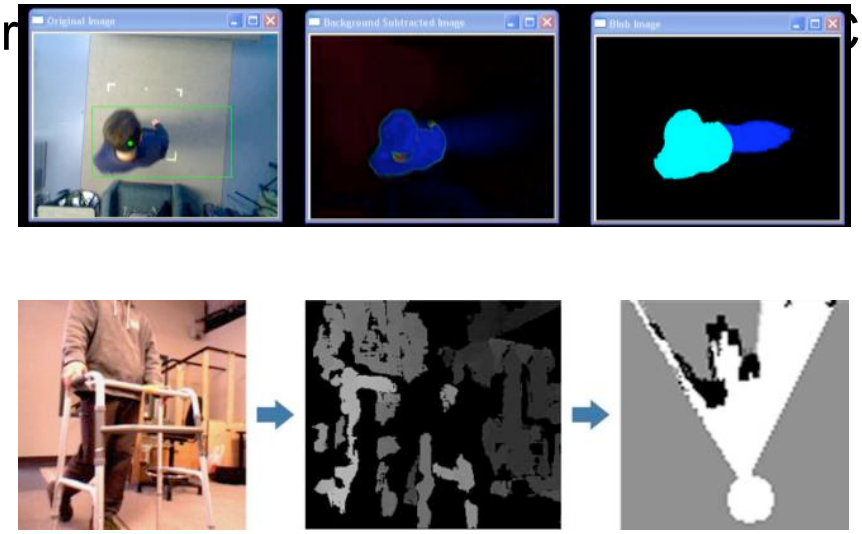
This true in both the home and institutions!

Motivation (Aging-in-place)

Assistive Technology *"Any item, piece of equipment, or product system, whether acquired commercially or off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities"*

[Cook & Hussey, 2000]





[Lee & Mihailidis 2005] [Mihailidis, Elinas, Boger, and Hoey 2007]

Background (Alzheimer's Disease)

- Worldwide: 18 million → 24 million by 2050 **(incidence *vs.* prevalence)**
- ~ One new case of AD every 70 seconds!
- 70% live at home
- Impairs explicit memory → difficulties in completing Activities of Daily Living (ADL)
- Current solution: caregiver
  - Constantly accompany the person and provide prompts, support, and monitoring
  - Frustrating for everyone
- Procedural memory is generally relatively spared
- **Task** completion difficult, **step** completion easier

Background (COACH)

An intelligent cognitive device that tracks a user through an ADL, providing cues when necessary

The COACH

Cognitive Orthosis for Assisting Activities in the Home

[Mihailidis, Boger, Candido, Hoey 2008]

Problem Definition (Ultimate Goal)

- Ultimate Goal

  To develop **intelligent assistive technology** that can promote wellness and **aging-in-place without extra burden** to the users

- Sub-problem

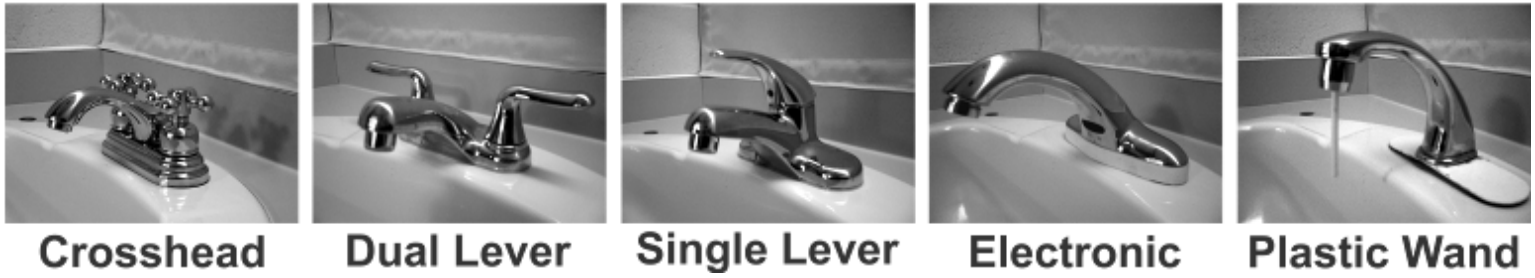
  To assist older adults with cognitive impairments in *activities of daily living*

  Handwashing

  - **Provide Assistance** (Reminder Prompts)
  - **Better Environment & Object Design** (High Usability)

Problem Definition (Specific Goal)

Automated Video Analysis to Determine Product Usability for Older Adults with Dementia



[Mihailidis, Boger, Fenton, Craig, Li 2008]

Sub-sub-problem

- Task Completion Time
- Errors & Difficulties
- Caregiver Assistance

Other Applications

- Leak Detection
- ...

Problem Definition (Scope)

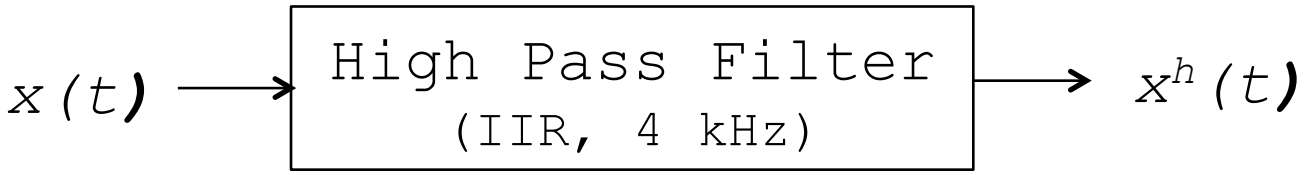
- Detect the Flow of Water in a Bathroom Sink
  - Audio Processing / Computer Vision
- Observe the Current State within a Handwashing Process
  - Turning the water on/off, adjusting the water, ...
  - Temporal Segmentation / Action Detection
- Identify Difficulties / Errors / Assistances

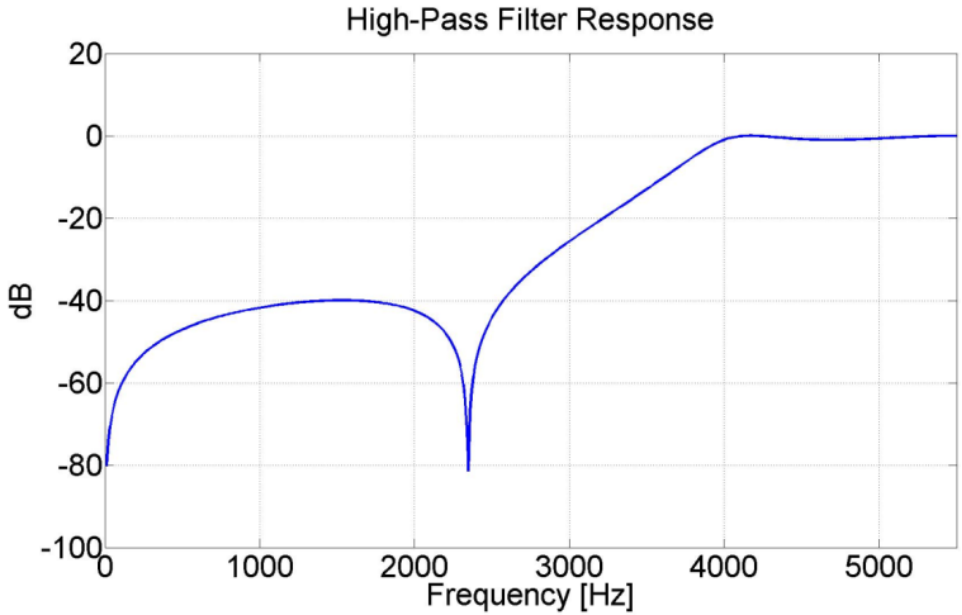
Water Detection

- Audio Features
- Detect the Sink Zone
- Image Features
- Classification
  - Logistic Regression
  - Support Vector Machines
  - Multilayer Perceptron
  - *k* Nearest Neighbours

Water Detection (Audio Features[1])

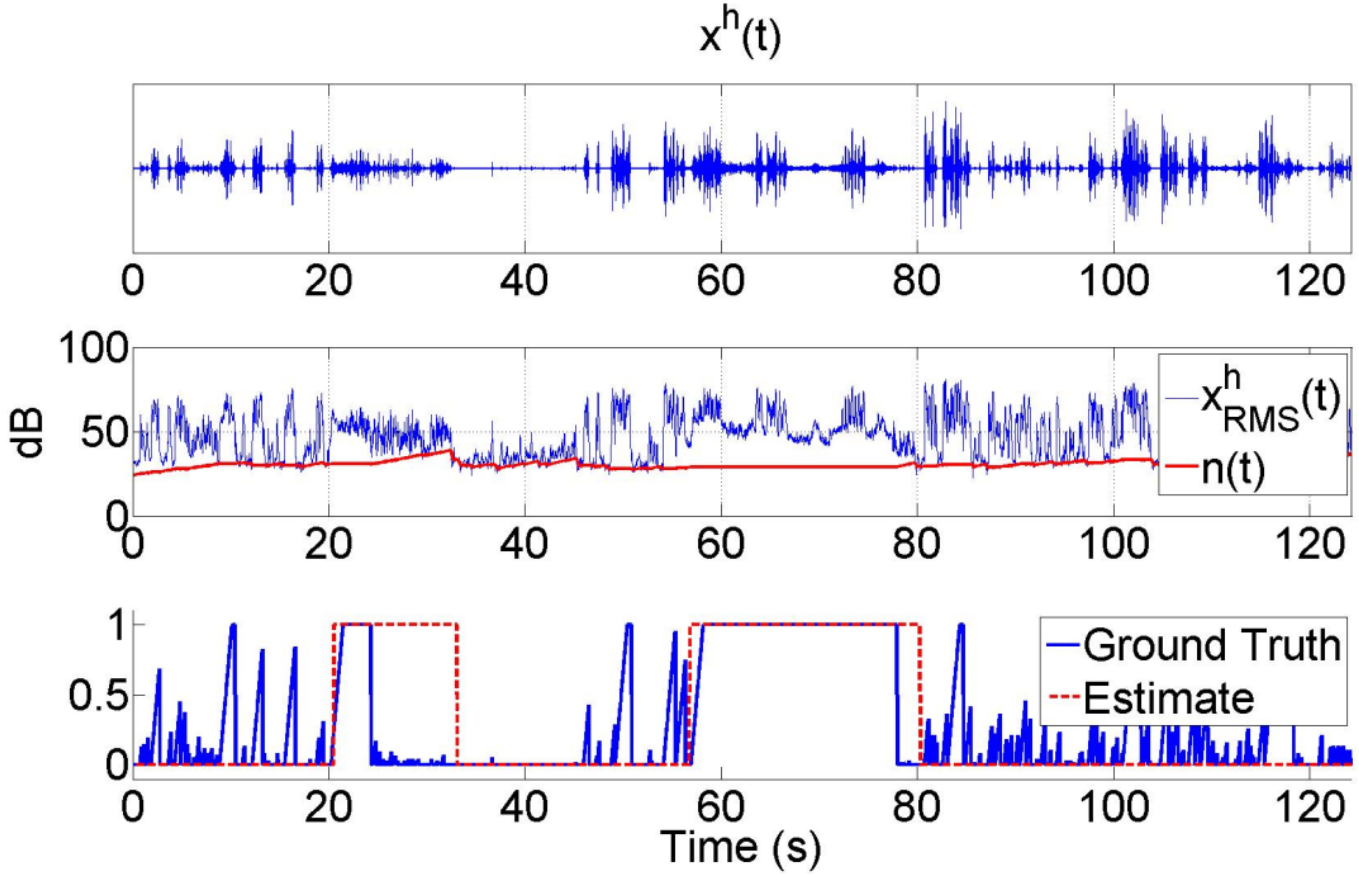
Adaptive Background Subtraction





Water Detection (Audio Features[2])

Adaptive Background Subtraction (cont'd)



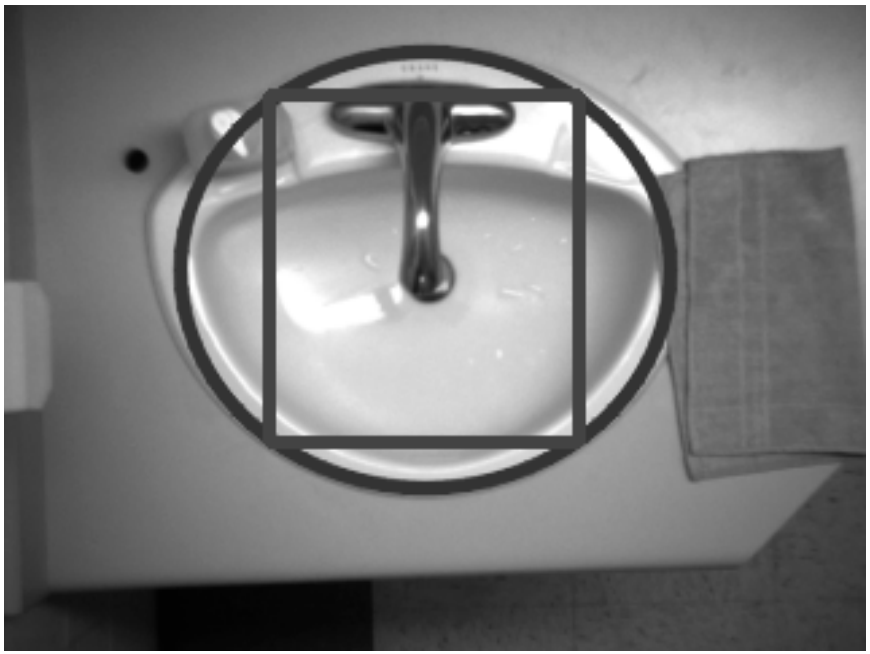
Water Detection (Audio Features[3])

- Signal to Noise Ratio $(snr = x^{h}_{rms} - n_{rms})$
- Zero Crossing Rate (zcr)
- Spectral Centroid (sc)
- Spectral Roll-off at 85% (sro)
- Spectral Flux (sf)
- Mel Frequency Cepstrum Coefficients $(MFCC, 19)$

- Vide: 15fps
- Audio: 11,025Hz
  - Packets: ~23ms
  - Overlap: ~10ms

→ 5 Audio Packets ~ Video Frame

Water Detection (Locate Sink Zone)

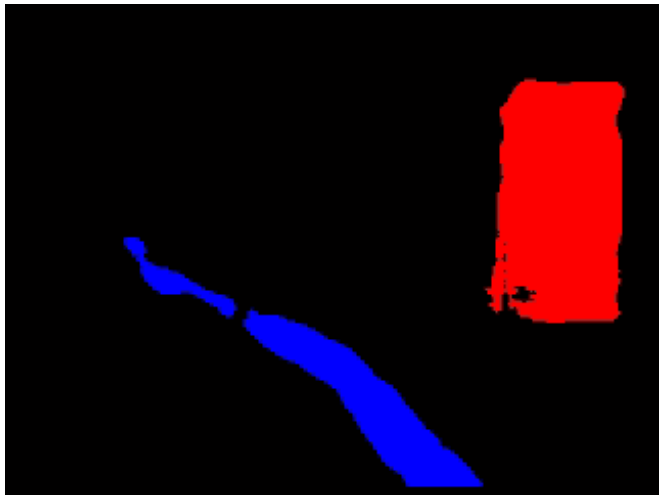


- Blob Detection
- Morphological Close (Dilate / Erode)
- RANSAC Ellipse Fitting

Water Detection (Video Features[1])

Water Detection (Video Features[2])

Original



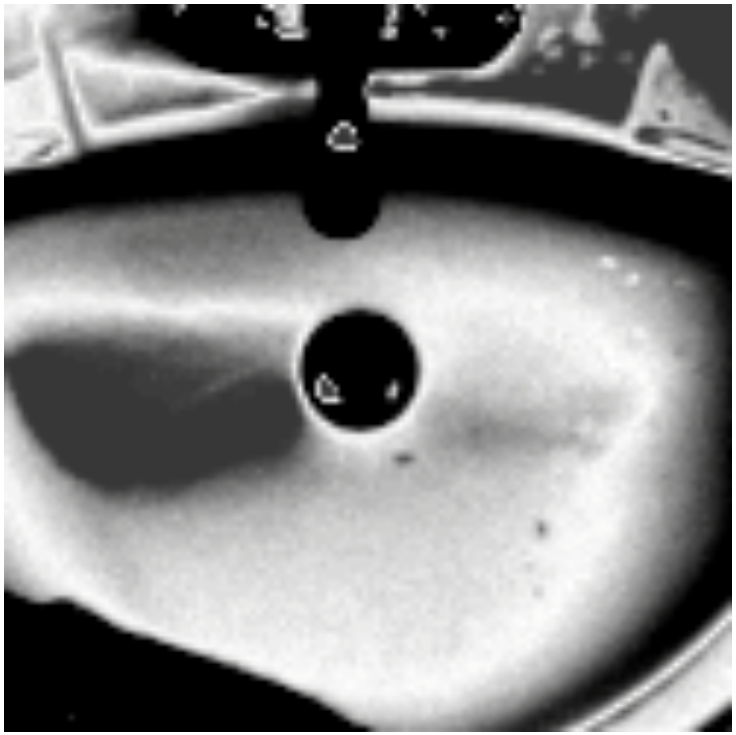
Particle Filter Tracking

How to Detect the Water Flow?

Water Detection (Video Features[3])

Original (Sink Zone)

$I(x,y,t)$



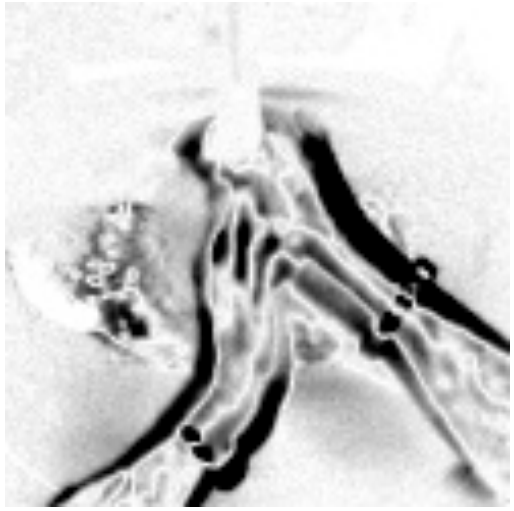
2nd Order Finite Difference

$\nabla_2[I](x,y,t) =$

$I(x,y,t) - I(x,y,t-2)$

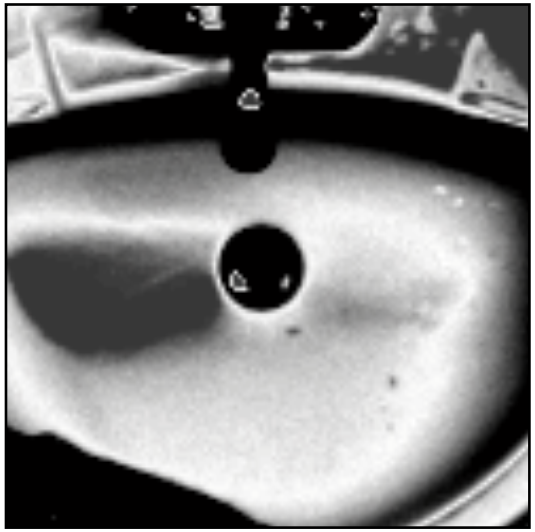
Water Detection (Video Features[4])

- Water √
- Hands X
- Shadows X



	Water	Hands	Shadows
Temporal Freq.	⬆	⬇	⬇
Spatial Freq.	⬆	⬇	⬇
Structure	⬇	⬆	⬆

Water Detection (Video Features[5])

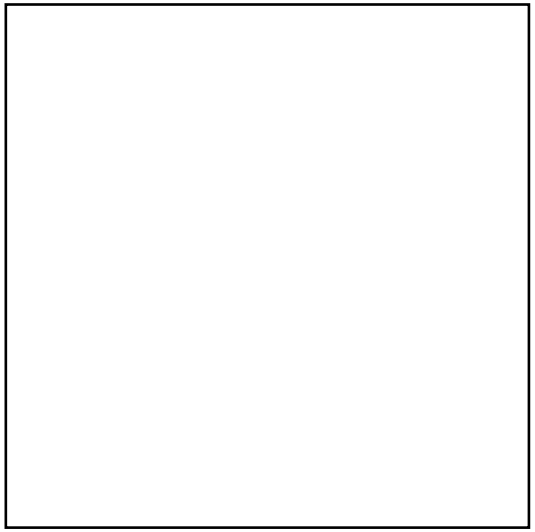


2nd Order Finite Difference

$$\nabla_2[I](x,y,t) = I(x,y,t) - I(x,y,t-2)$$

High Pass Filter

$$\nabla_2^h[I](x,y,t)$$



Apply (Hand) Mask

$$\nabla_2^h[I] - H_2^d$$

$$H_2^d(x,y,t) = H^d(x,y,t) - H^d(x,y,t-2)$$

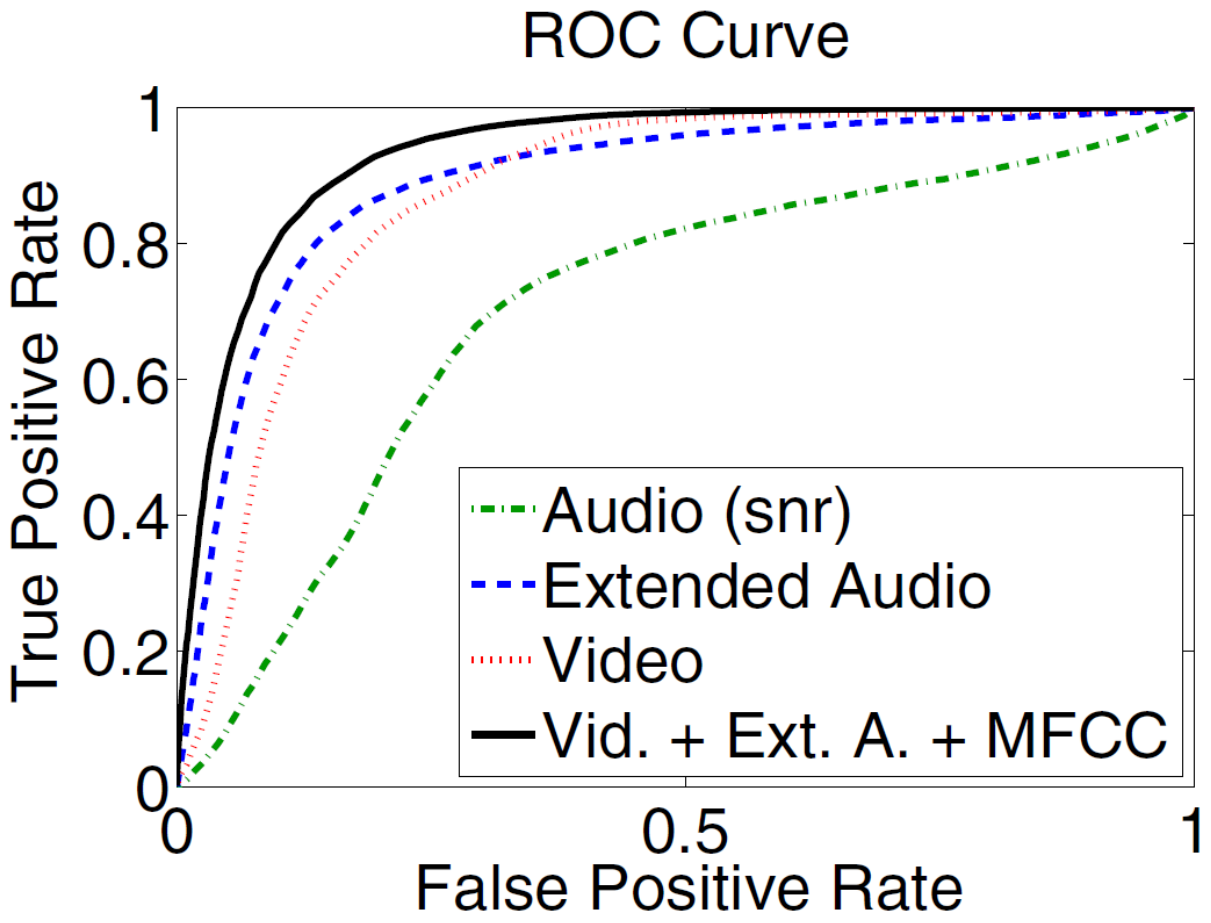
Water Detection (Classification[1])

	Classifier			
Features	*LR*	*SVM*	*MLP*	*kNN*
Audio (*snr*)	69.36	69.26	74.35	70.65
Extended Audio	79.21	78.97	78.54	78.96
Ext. Audio + MFCC	83.25	80.78	79.18	80.26
Video	80.81	81.00	83.02	80.92
Video + Audio	85.94	83.87	84.76	83.77
Video + Ext. Audio	86.31	85.73	86.43	84.44
V. + Ext. A. + MFCC	88.76	88.34	88.09	86.30

LR: Logistic Regression, **SVM**: Support Vector Machines,
MLP: Multilayer Perceptron, ***k*NN**: *k* Nearest Neighbour

[Taati, Snoek, Giesbrecht, and Mihailidis 2010]

Water Detection (Classification[2])



[Taati, Snoek, Giesbrecht, and Mihailidis 2010]

Conclusions

- Detecting the Flow of Water
  - Sensor Fusion `(Audio AND Video > Audio OR Video)`
  - Logistic Regression
- Applications
  - Usability Analysis
  - Reminder Prompts
  - ...

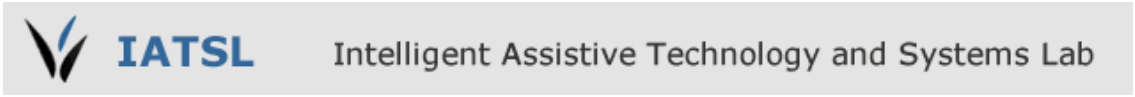
Future Work

- Action Detection
  - See you in San Francisco! (CVPR-4HB)
- Detect and Classify Errors / Difficulties / Assistance
  - Errors: Wrong Location / Wrong Operation / ...
  - Assistance: Generic / Specific, Verbal / Visual / Demo/ Assist
- Faucet Design Usability Analysis
- Extend to Other Products and Environments

Acknowledgments

- Sponsors
  - **NIDDR RERC on Universal Design**

- Contact Us



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