Shoes as a Platform for Vision

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Cameras on Shoes?

- Isn't the view really boring?
  - not if you care about where and how we're walking (local environment)
- Isn't there too much movement?
  - not when the foot is planted
- Isn't it impractical?
  - cameras are getting cheaper and smaller

Sensible Shoes

- Shoe based wearables
  - gambling
  - power production
  - user interfaces
- Shoe advantages
  - Comfortable mounting place
  - Shoe mounted gadgets are common
  - Worn regularly
  - Shoes can be expensive

Outline

step 1 the platform

step 2 gait analysis using vision

step 3 special times to watch the world

step 4 future directions

Platform Shoe

- Forward mounted camera (not looking up!)
- Orientation sensor for independent evaluation

Some Footage

Those Special Moments

- The planted foot is the only part of the body that is reliably stationary with respect to the world during walking and standing
- When the foot is planted, it has:
  - Canonical orientation
  - Constrained location
  - Stable placement
- Efficient visual detection is possible:
  - For this state
  - For the surrounding context in this state

Plant Detection

- darker image
- motion blur
- large time derivative

- lighter image
- motion blur
- large time derivative

- average image
- no motion blur
- small time derivative

The Features

Image brightness

Temporal derivative

Spatial derivative

Combined & Filtered

$$I_0 = \frac{1}{N}\sum_{x,y} I(x,y), \quad N = \sum_{x,y} 1 \tag{1}$$

$$\Delta I_t = \frac{1}{I_0 N}\sum_{x,y} |I(x,y,t) - I(x,y,t-1)| \tag{2}$$

$$\Delta I_x = \frac{1}{I_0 N}\sum_{x,y} |I(x,y,t) - I(x-1,y,t)| \tag{3}$$

$$s = \alpha \Delta I_t - \beta \Delta I_x - \gamma I_0 \tag{4}$$

Gait Analysis

Spatial derivative

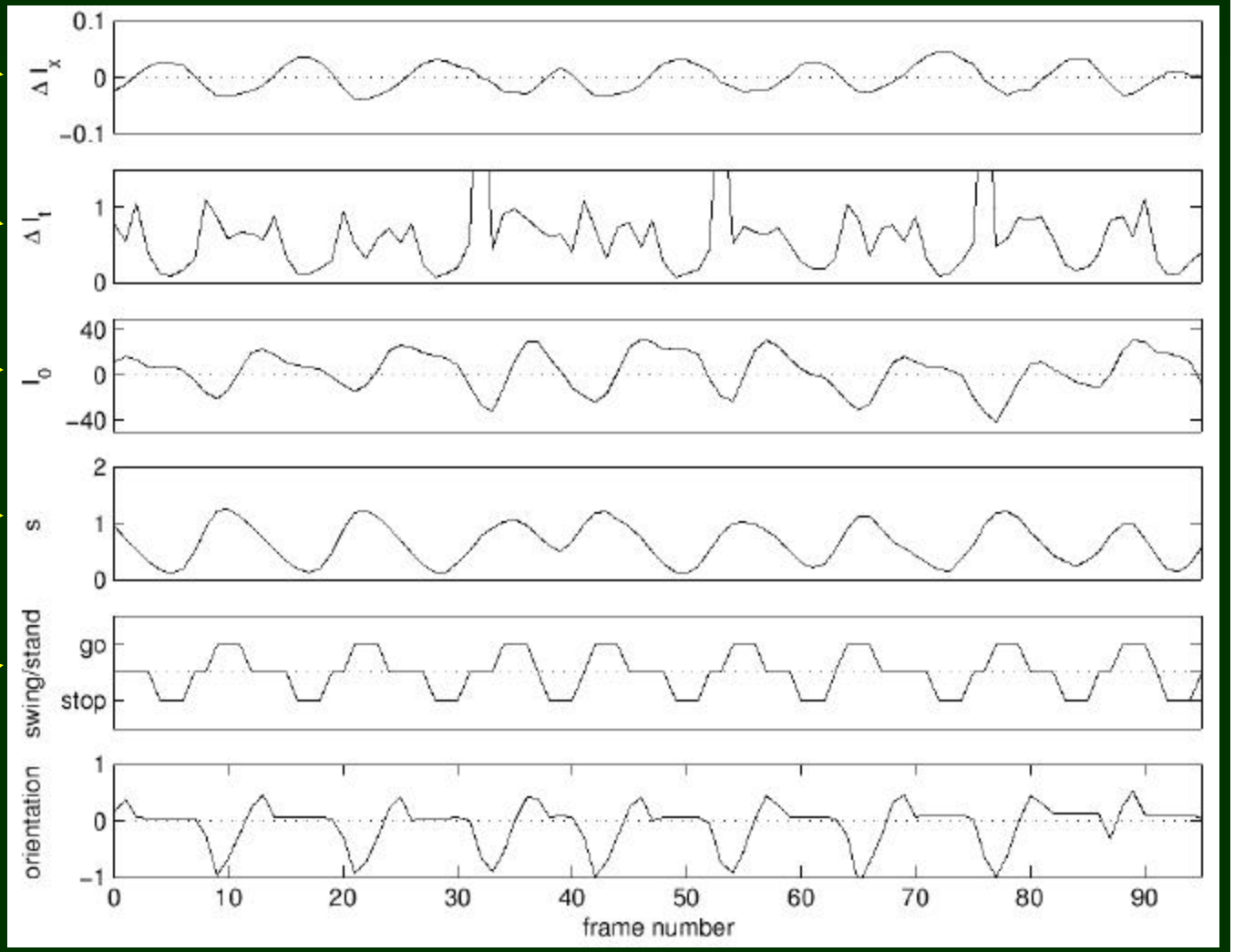
Temporal derivative

Image Brightness

Combined & Filtered

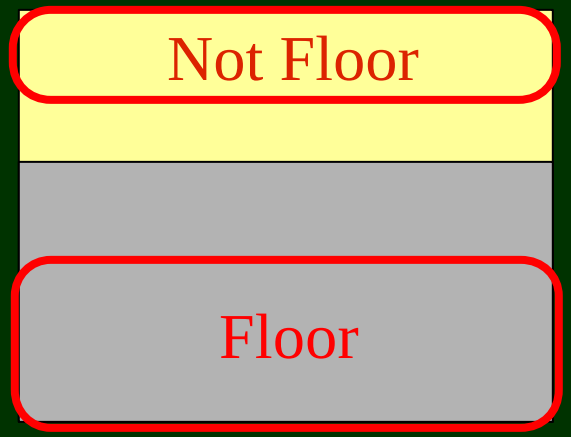
Swing/Planted detection

Orientation

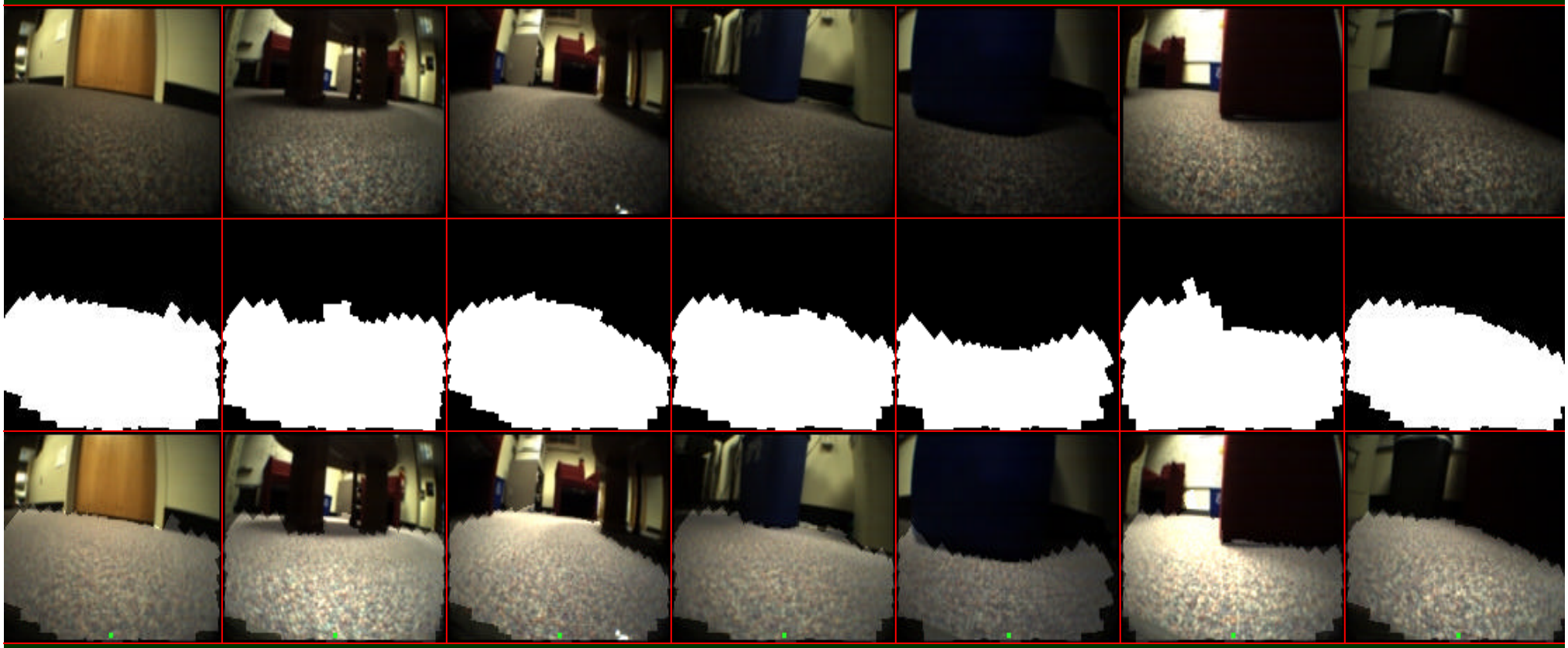


Making Use of the Special Frames

- strong prior based on the horizon line, position, and orientation
  - Floor Segmentation
  - Floor Recognition



Floor Segmentation



Floor Recognition

	classification frequencies for floor samples							
floor	1	2	3	4	5	6	7	8
1	194	0	28	14	2	13	0	0
2	0	30	0	0	0	0	0	0
3	0	0	4	0	0	0	0	0
4	2	0	3	37	0	0	0	0
5	0	0	0	0	31	0	0	0
6	0	0	0	0	0	149	0	0
7	0	0	0	0	0	0	36	15
8	0	0	0	0	0	0	0	6

Conclusions

- a shoe mounted camera is well placed
  - only stable mount during walking
  - purely visual gait analysis
  - special frames
    - floor segmentation
    - floor recognition
- issues
  - lens cleaning and lens safety
  - running
  - privacy

Future Directions

- Automated cartography
- Navigation assistant (walking hazard detection)
- Localization of nearby people by feet and legs
- Advanced floor recognition
- Recognition of common nearby objects (chairs, tables, walls, trash cans, etc.)
- Outdoor operation
- Camera on each foot

Footnote

- Puns we used
  - footage
  - sensible shoes
  - platform shoe
  - issues
  - features
  - step
  - footnote
  - leg up
- Puns we (almost) spared you
  - baby step
  - giant leap
  - floored
  - bootstrap
  - footprint
  - so shoet me
  - shoe on the other foot
  - best foot forward
  - both feet on ground
  - let's run with this
  - first step
  - stumble across
  - sole
  - grounding
  - run into a problem
  - kick start
  - trip over
  - firm foundation
  - skip over
  - step by step
  - caught flat footed
  - up and running