



The SmartCane System: An Assistive Device for Geriatrics

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Outline

- **UCLA Wireless Health**
- Smart Assistive Devices Motivation
- The SmartCane System
- Results
- Next steps
- Conclusion

Wireless Health @ UCLA

- **Campus Community**
 - School of Medicine
 - Medical Center
 - School of Engineering
 - School of Nursing
 - School of Public Health
 - College of Letters & Science
 - Anderson School of Management
- **Industrial Partners**
 - Microsoft
 - Qualcomm
 - National Instruments
 - Nokia
- **Unique approach**
 - End-to-end integration from sensing to medical informatics to call center
 - Develop and verify new healthcare methods and services
 - Establish standards for efficacy, reliability, interoperability, and security



Wireless Health Programs Underway

■ Disease Management

- Monitoring as intervention for effects of diabetic neuropathy
- Wireless shoe system sensing
- In commercialization phase

■ Health Promotion

- UCLA and LA County Public Health partners
- On-line monitoring of individual activity and nutrition through biomarker sensors

■ Health Monitoring

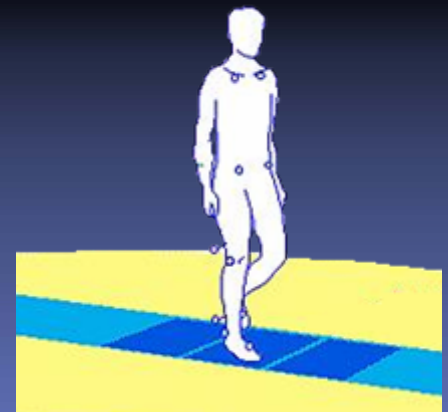
- First responders health and safety (DHS)

■ Pharmaceutical Management

- Multiple critical applications

■ Wireless Biomechanics

- Smart assistive devices for reduction of risk of falls (cane, crutch, walker)
- Personal Gait Lab
- UCLA and VA Geriatrics
- Pilot studies at LA VA Hospital



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Current Assistive Devices in Geriatrics

■ Falls

- Currently the leading cause of death from injury in the elderly ¹.

■ Conventional Assistive Devices ²

- Critical in reducing the risk of falls
- Relied upon by over 4 million patients in the U.S.
- Provide physical support and supplementary sensing feedback to patients.



■ Risks

- May contribute to serious adverse effects that instigate falls.
- Due to a lack of training on how to properly use the device ³.



1 Kannus et al, Fall-induced injuries and deaths among older adults, JAMA, 1999.

2 Rubenstein et al, Falls and their prevention in elderly people: What does the evidence show?, Medical Clinics of North America, 2006.

3 Gupta et al, How accurate is partial weight bearing?, J Bone Joint Surg Br, 2004.

Smart Assistive Devices for Geriatrics

- **Remote monitoring and guidance of patients**
 - Promote proper use of assistive devices ⁴.
 - Reduce risk of injury and falls ⁵.
- **Combine advances in technology**
 - signal processing, embedded computing, and wireless communication
 - Low cost, long operating lifetime embedded computing systems
- **Capabilities**
 - Adaptive to specific individuals
 - Tolerant to faults and system performance limitations



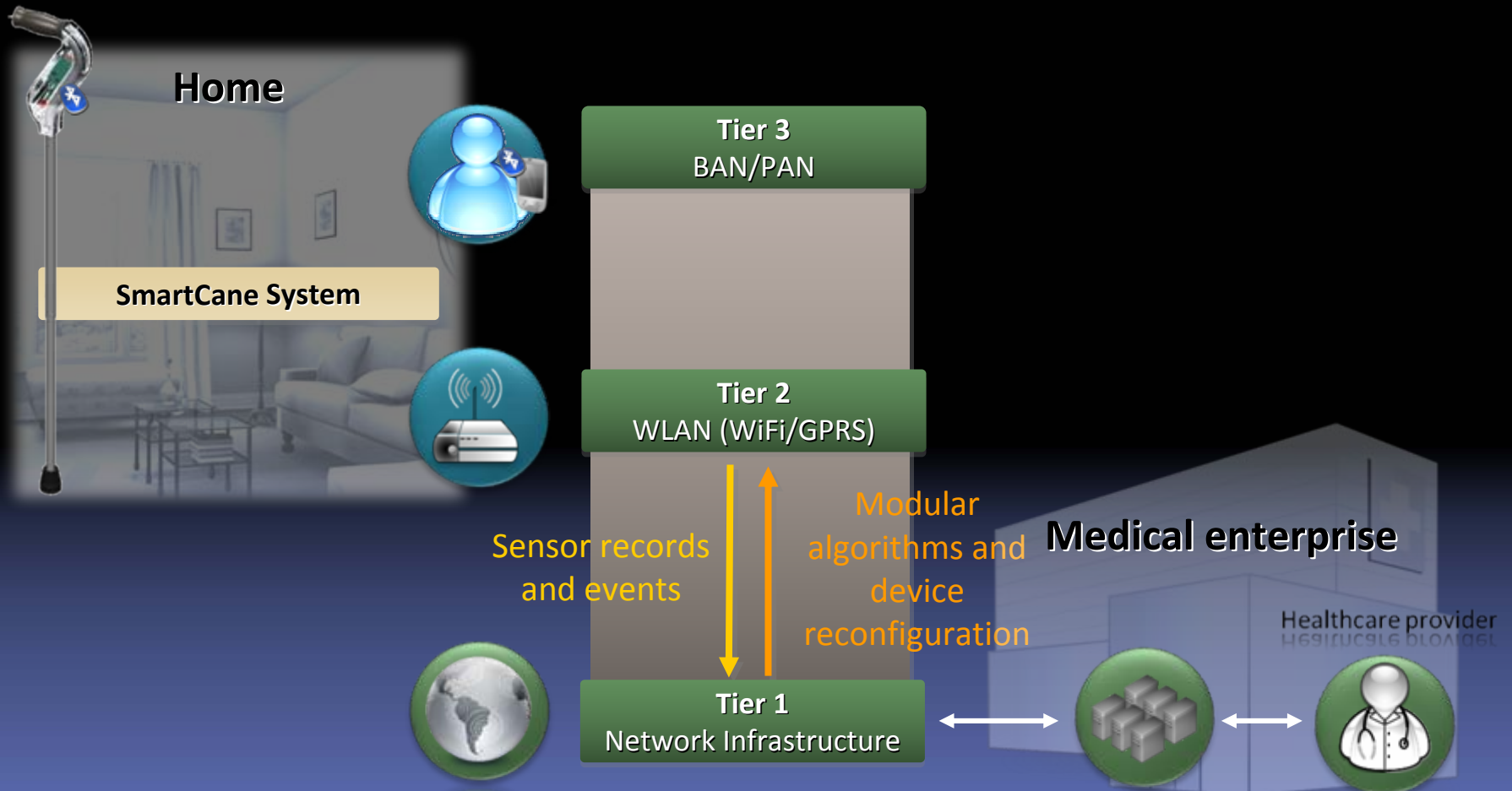
4 Bateni & Maki, Assistive devices for balance and mobility: benefits, demands, and adverse consequences, *A Arch Phys Med Rehabil*, 2005.

5 Berg & Cassels, *The Second Fifty Years: Promoting Health and Preventing Disability*, National Academy Press, 1992.

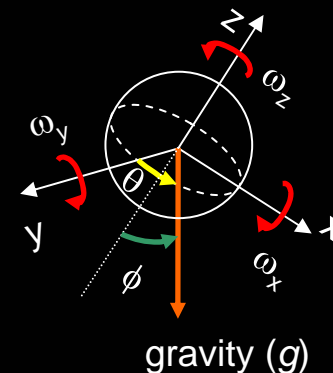
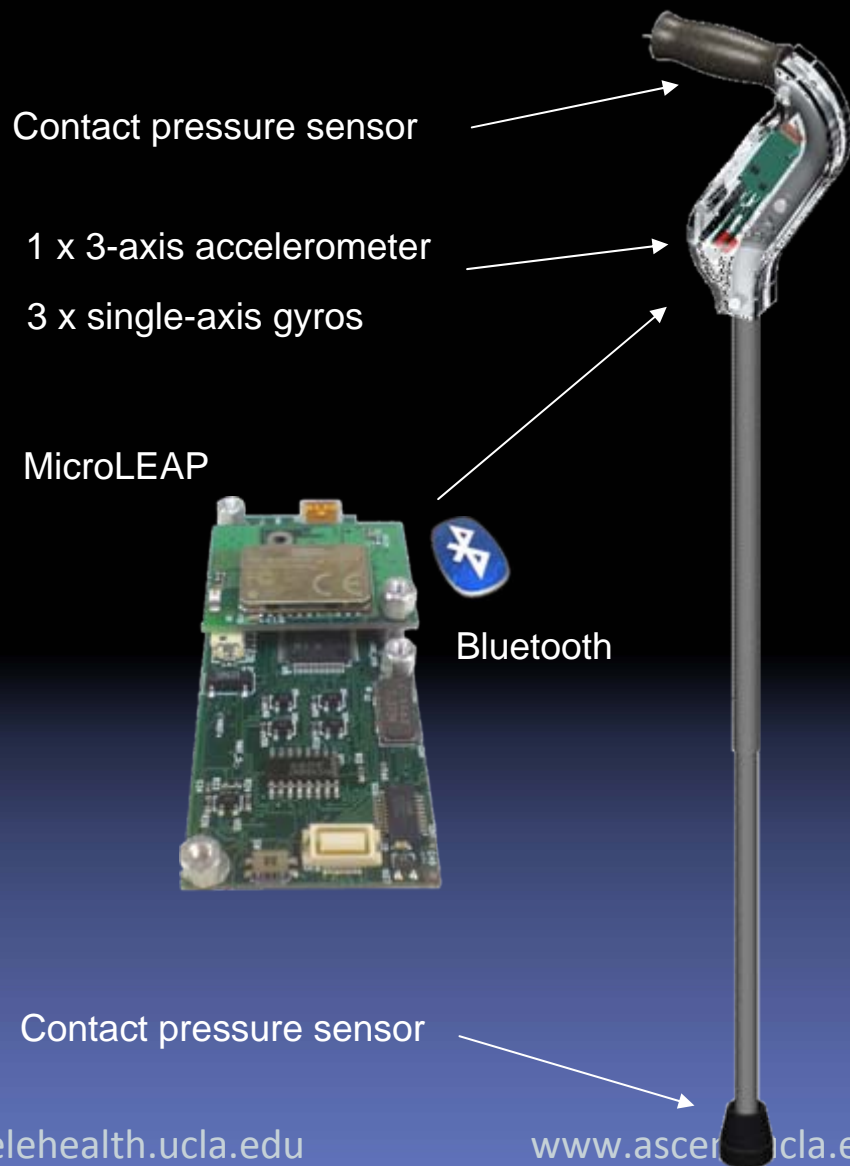
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SmartCane System Network Architecture



The SmartCane System



■ Sensing

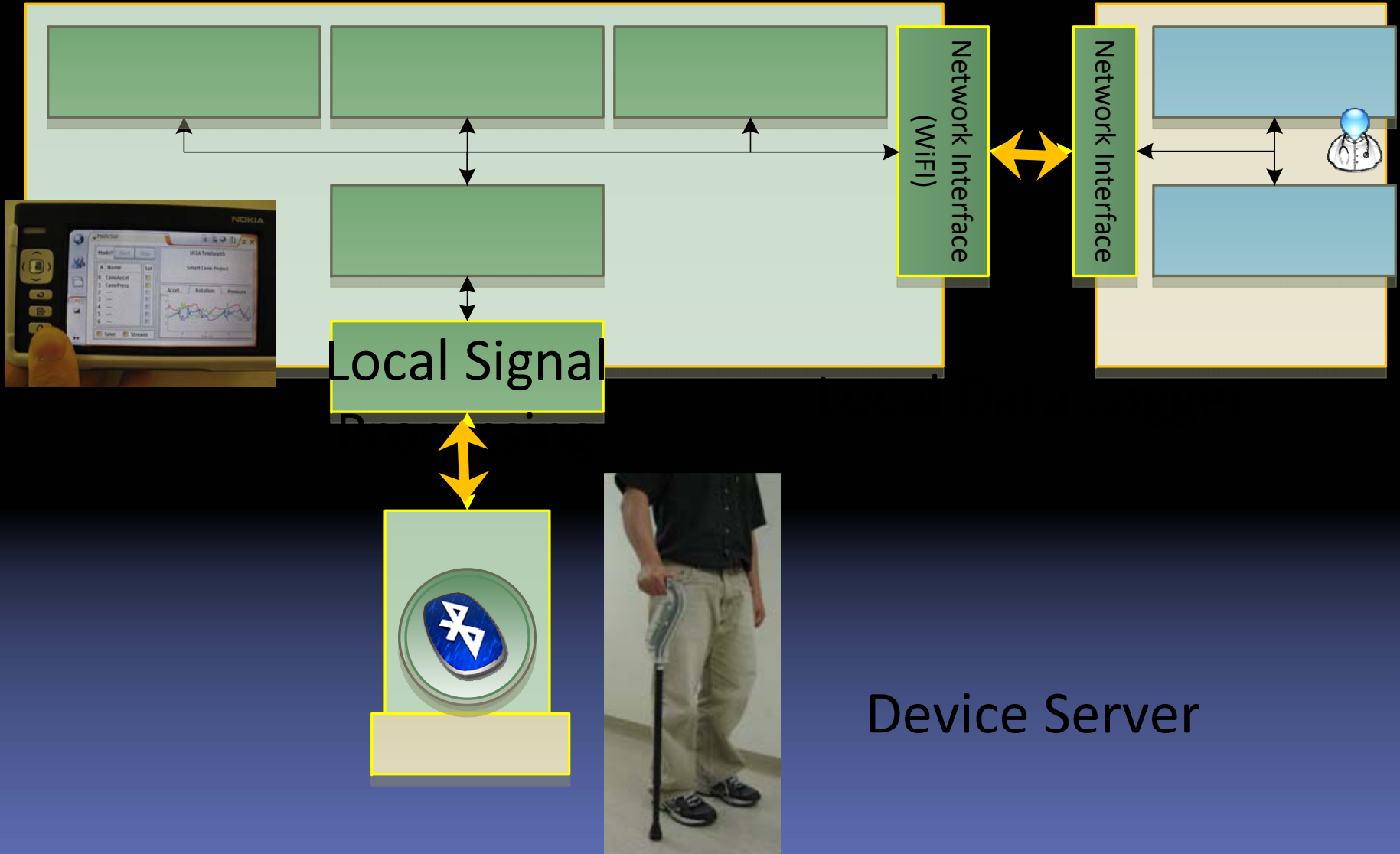
- 3-Dimensional acceleration and orientation
- 3-Dimensional rotation
- forces
 - handle grip
 - tip downward

MicroLEAP Wireless Sensor Node

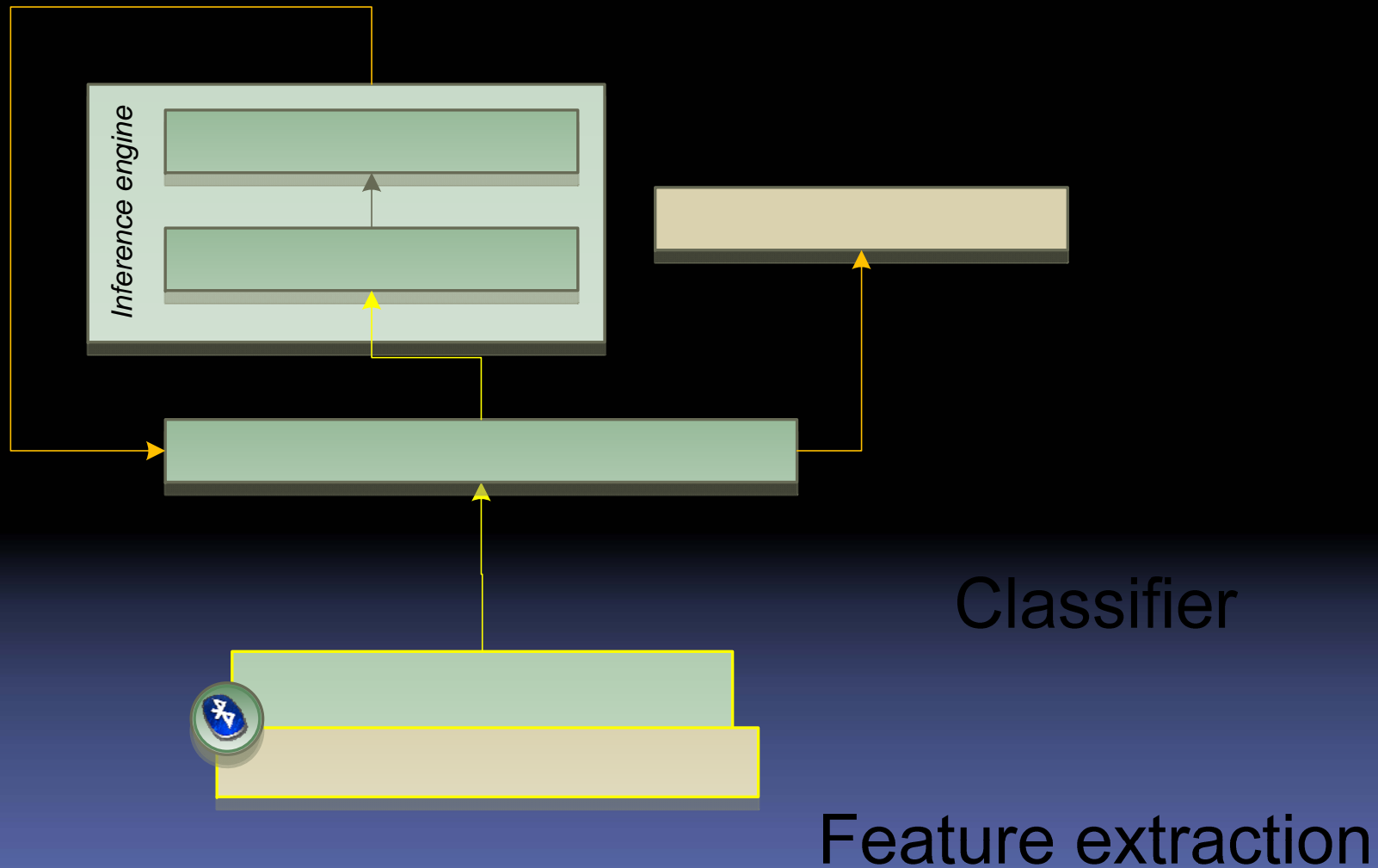
- **Processing Unit**
 - TI MSP430F1611 microcontroller
 - 8Mb external flash
- **Radio**
 - Class 2 Bluetooth module
- **Sensing**
 - 8-channel, 16-bit ADC
 - Replaceable front end circuit board
 - 3-D accelerometer, gyros
 - ECG circuits
- **Energy Management Unit**
 - Current-sensing circuit
 - 12-bit MSP430 ADC
 - Software-enabled power switches
- **Open source system**
 - <http://cvs.cens.ucla.edu/viewvc/viewvc.cgi/leap/>



Software Architecture

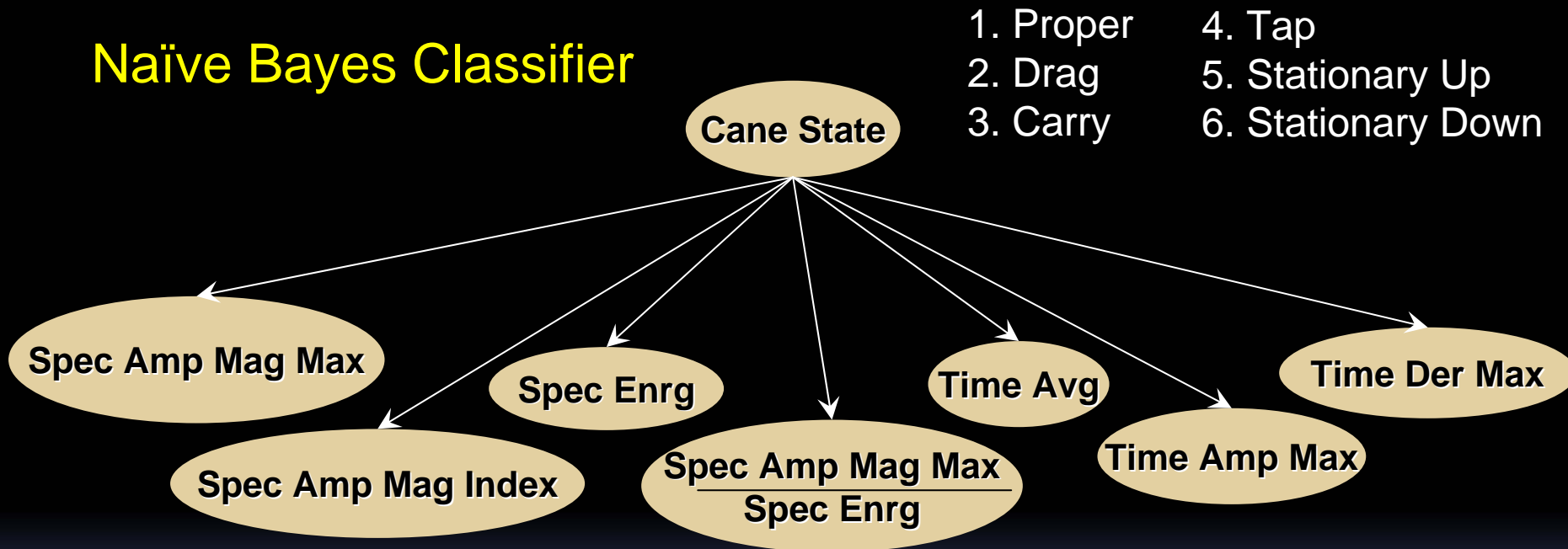


Local Signal Processing



Inference Engine

Naïve Bayes Classifier



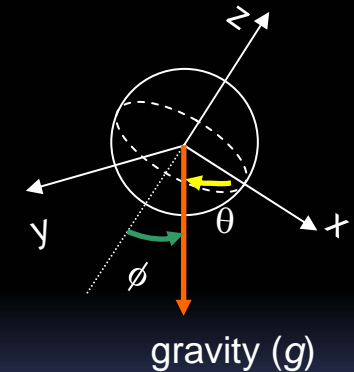
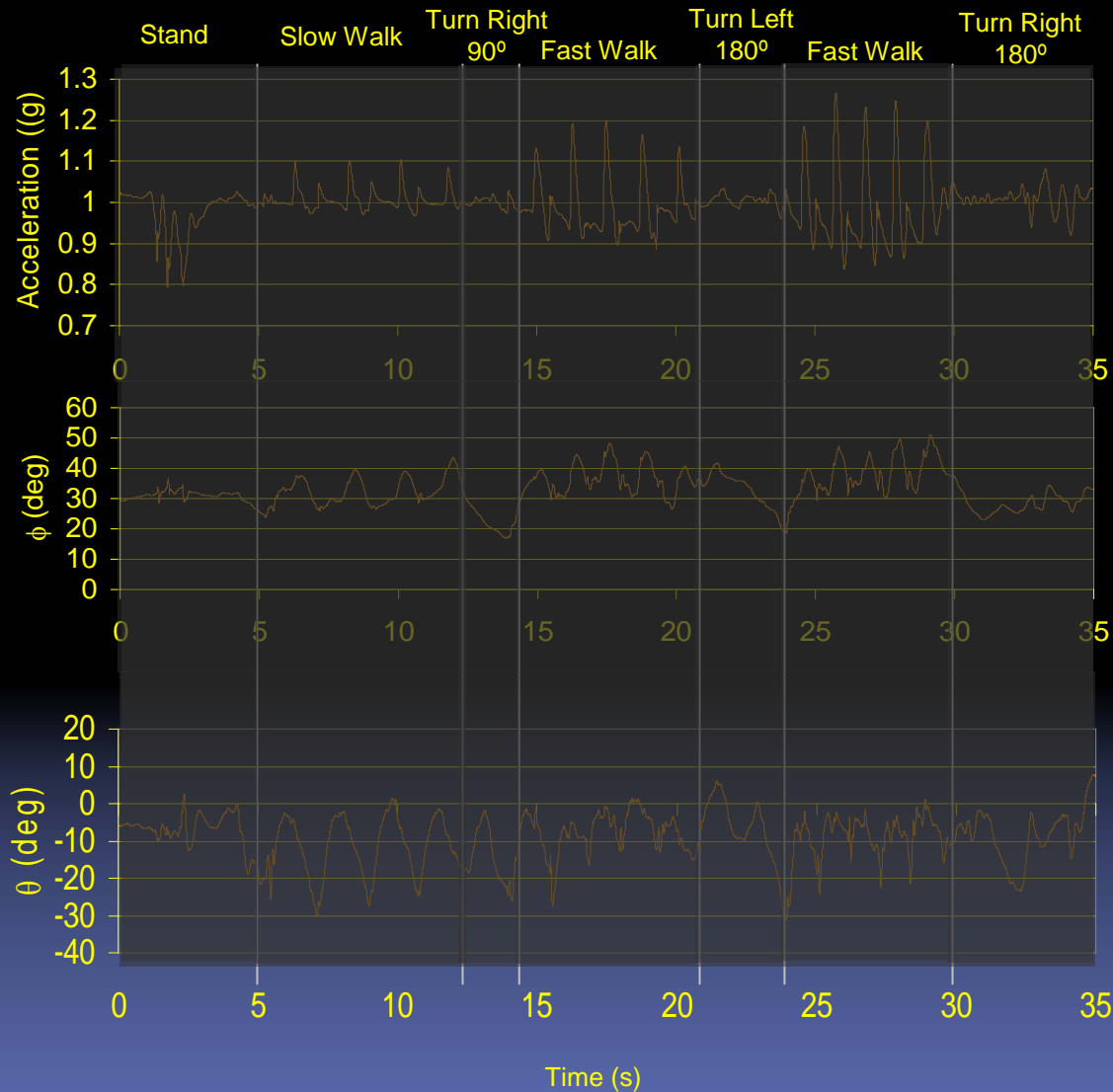
7 features are extracted from each sensor channel consisting of

- Accelerometer XYZ
- Gyro XYZ
- Pressure grip
- Pressure tip

Outline

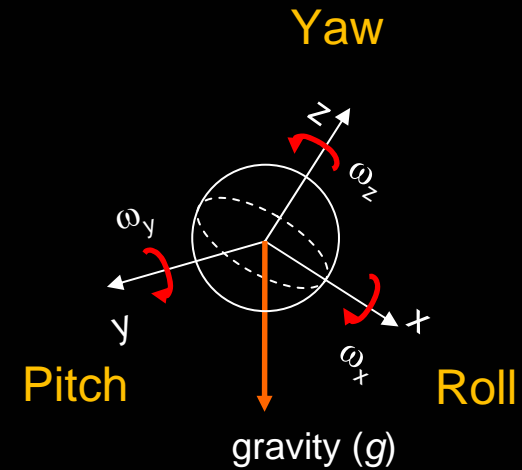
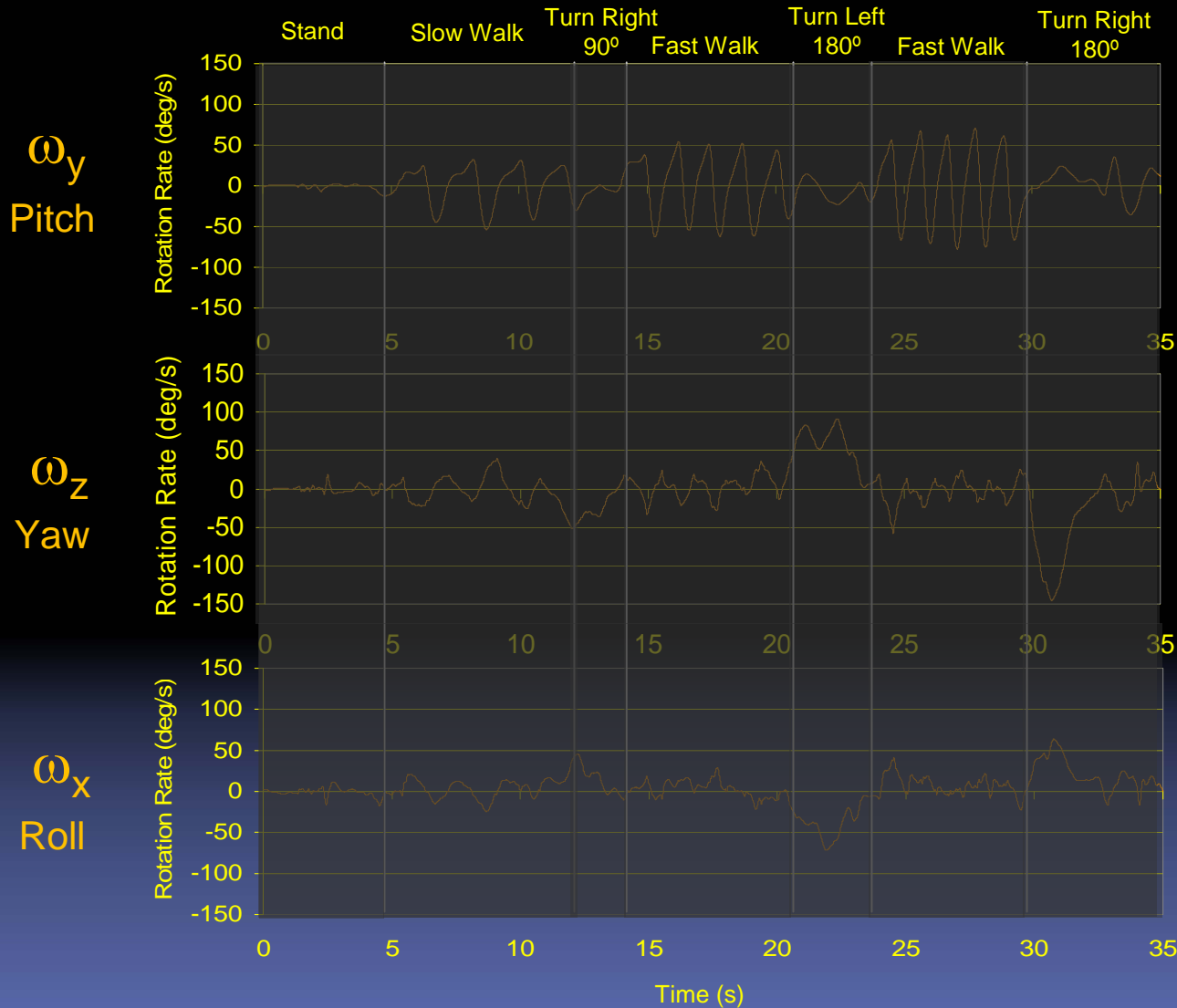
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Accelerometer Data



- ρ = magnitude of acceleration
- ϕ = tilt angle from vertical axis
- θ = tilt angle on side

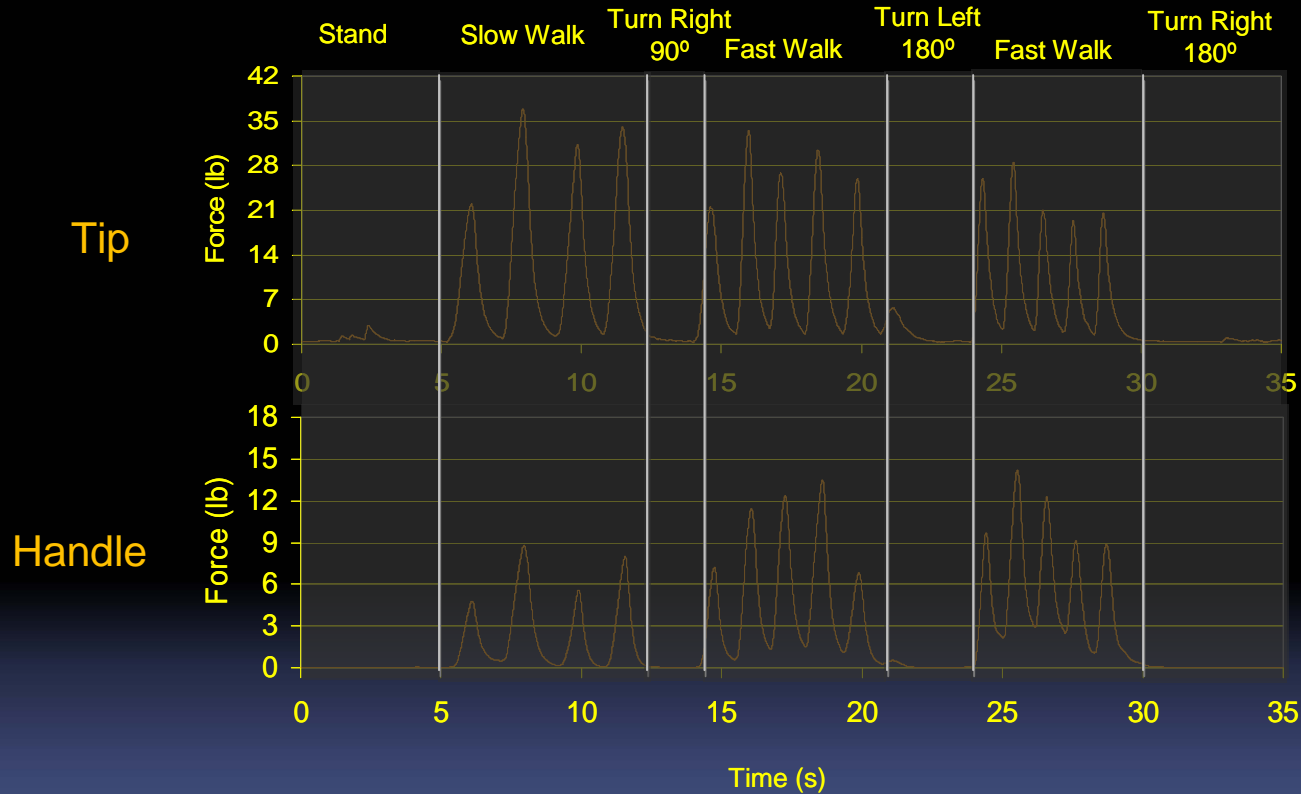
Gyroscope Data



Pitch = swing rate of the cane

Yaw & Roll detect the turns

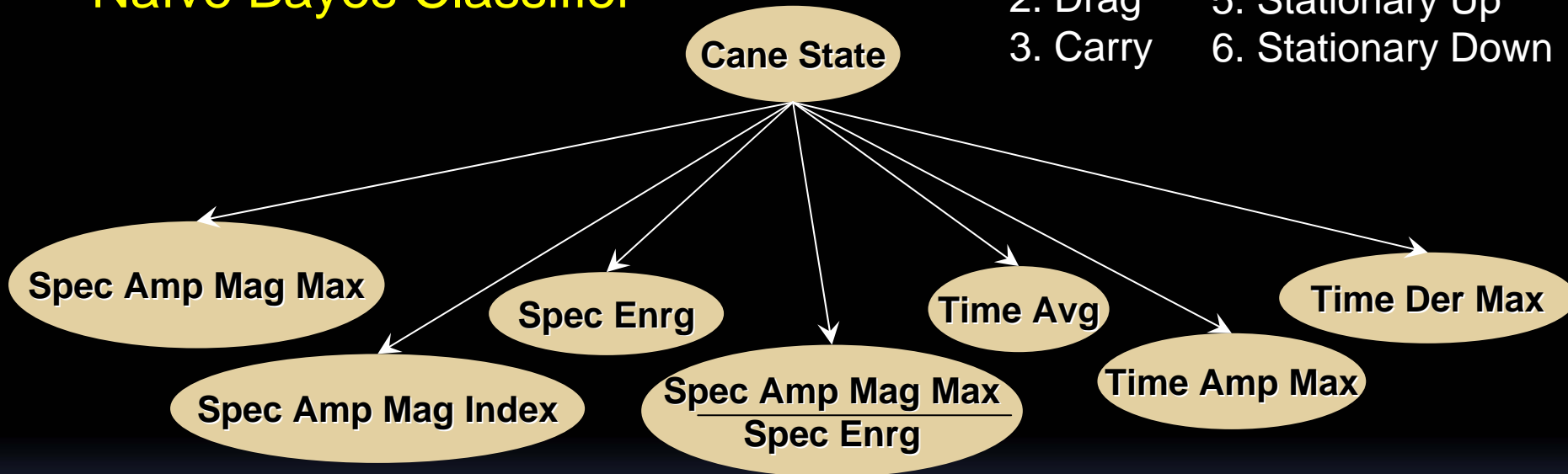
Pressure Sensor Data



Local Signal Processing

Naïve Bayes Classifier

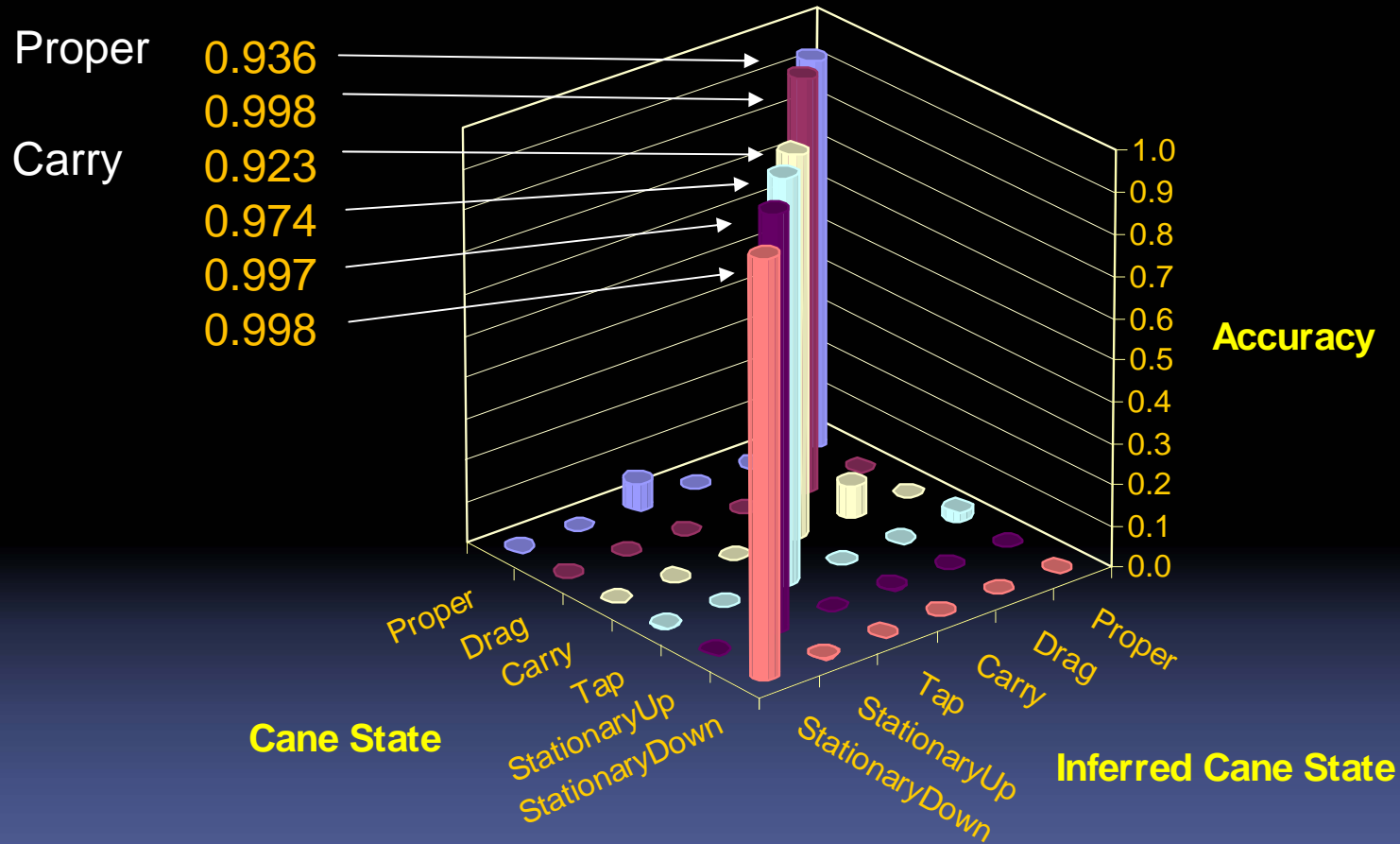
1. Proper
2. Drag
3. Carry
4. Tap
5. Stationary Up
6. Stationary Down



7 features are extracted from each sensor channel consisting of

- Accelerometer XYZ
- Gyro XYZ
- Pressure grip
- Pressure tip

Inferred Cane State Accuracy



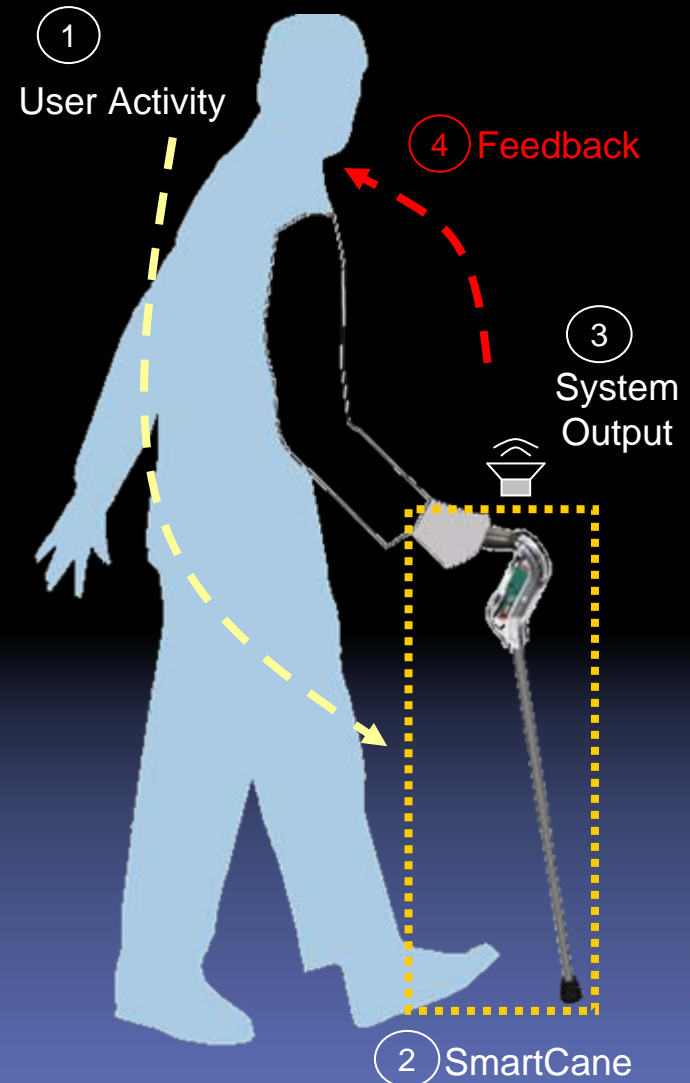
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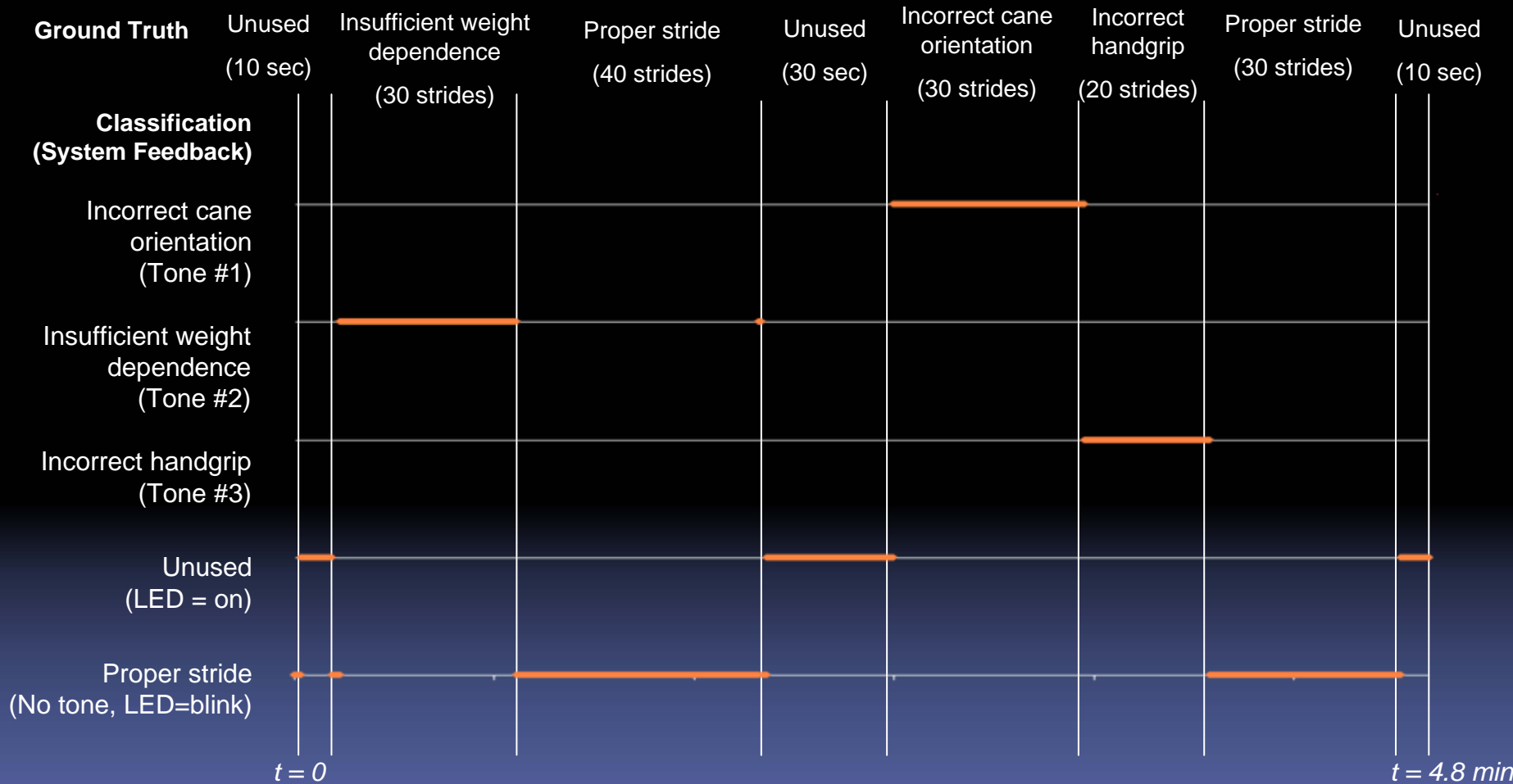
Current Activity: Patient Feedback

■ Provide patient feedback by means of

- Voice
- Vibration
- Acoustic tones
 - Tap
 - Loose grip
 - Hold side way

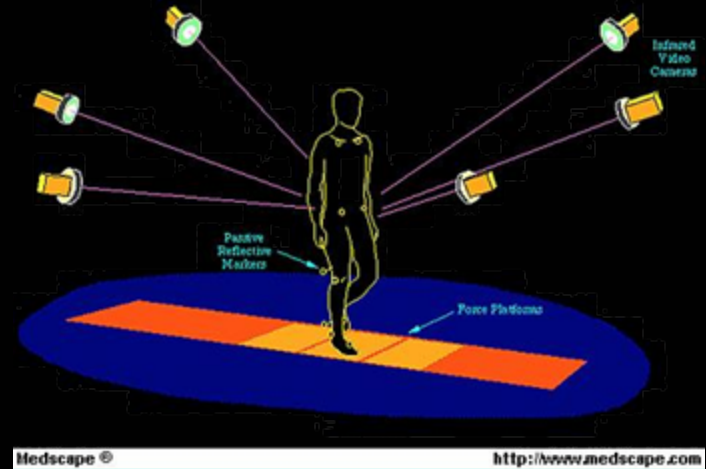


Patient Feedback



Next Step: Gait Biomechanics

- **Gait and motion analysis is critical**
 - Geriatric care
 - Rehabilitative care
 - Workplace safety
- **Measurements**
 - Dynamic joint angle
 - Dynamic limb motion
 - Dynamic measurement or inference of forces
- **Facilities**
 - Requires large scale laboratory
 - Video motion tracking systems
 - Trained, dedicated personnel
- **Automatic selection of sensors to turn on**
 - Extend battery life of body-worn sensors



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Conclusion

- **Implemented the SmartCane system**
 - Based on commercially available microsensor, computing, and wireless technologies.
 - Utilizes the capabilities provided by the Wireless Health architecture
 - Caregivers can monitor the cane usage in real-time
- **Presented data from a patient using the SmartCane system**
 - Showed clear differences in the patient's usage of the cane.
- **Presented cane state inference results from Naïve Bayes classifier**
- **SmartCane will enable future applications**
 - Patients are actively guided towards safe behavior
 - Reduce the risk of falls.

