The SmartCane System: An Assistive Device for Geriatrics

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Outline

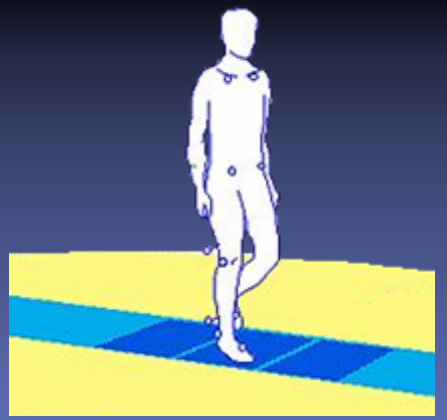
- UCLA Wireless Health
- Smart Assistive Devices Motivation
- The SmartCane System
- Results
- Next steps
- Conclusion

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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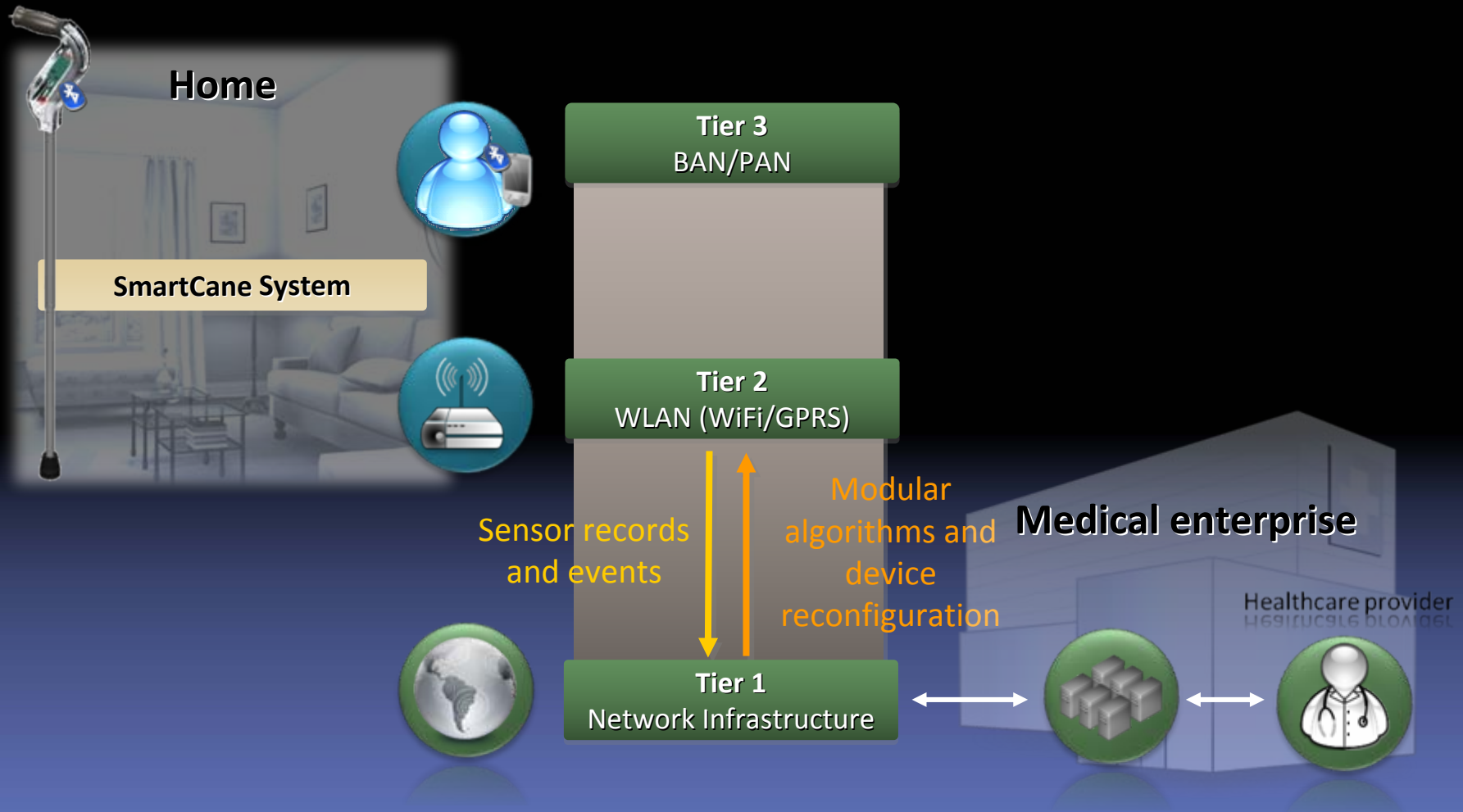
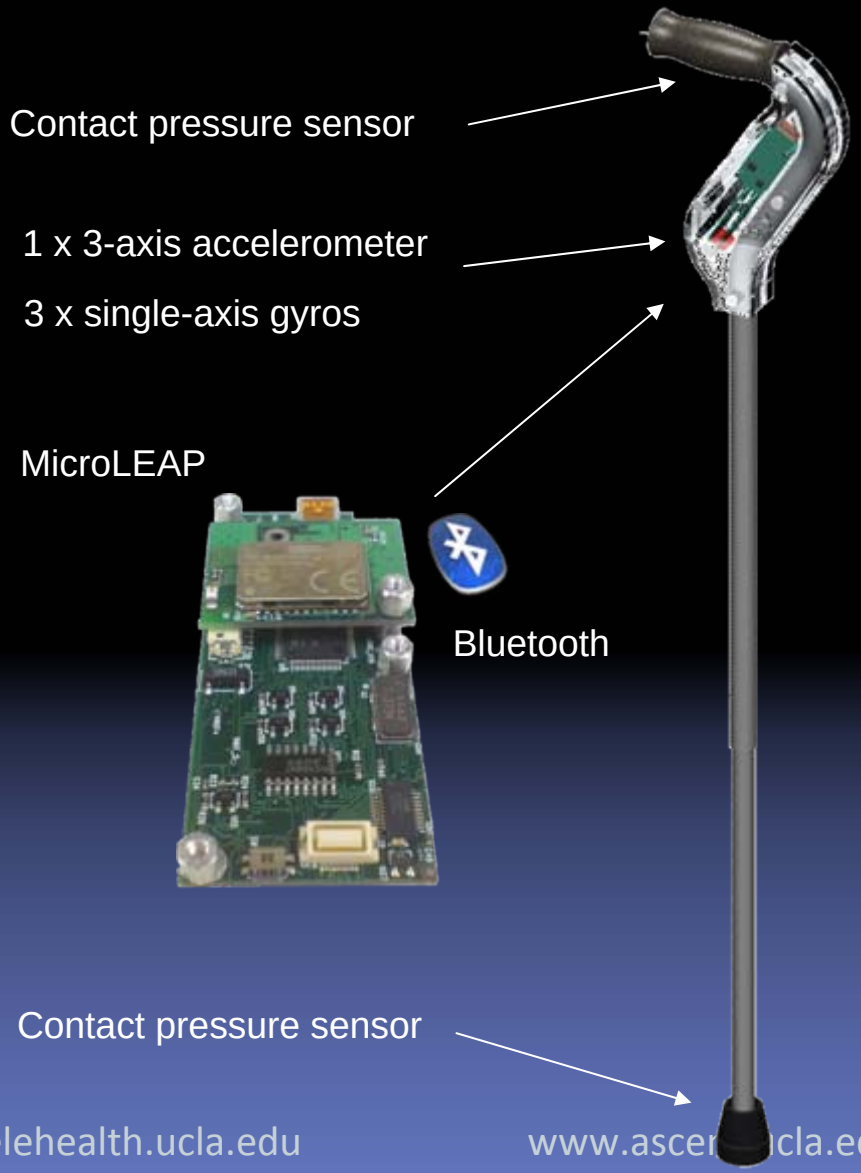
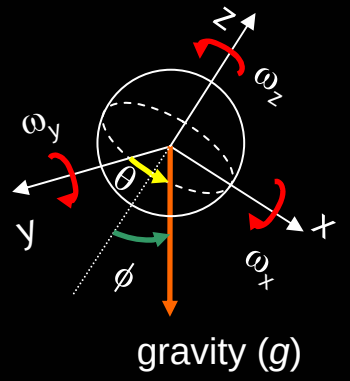
SmartCane System Network Architecture



The SmartCane System



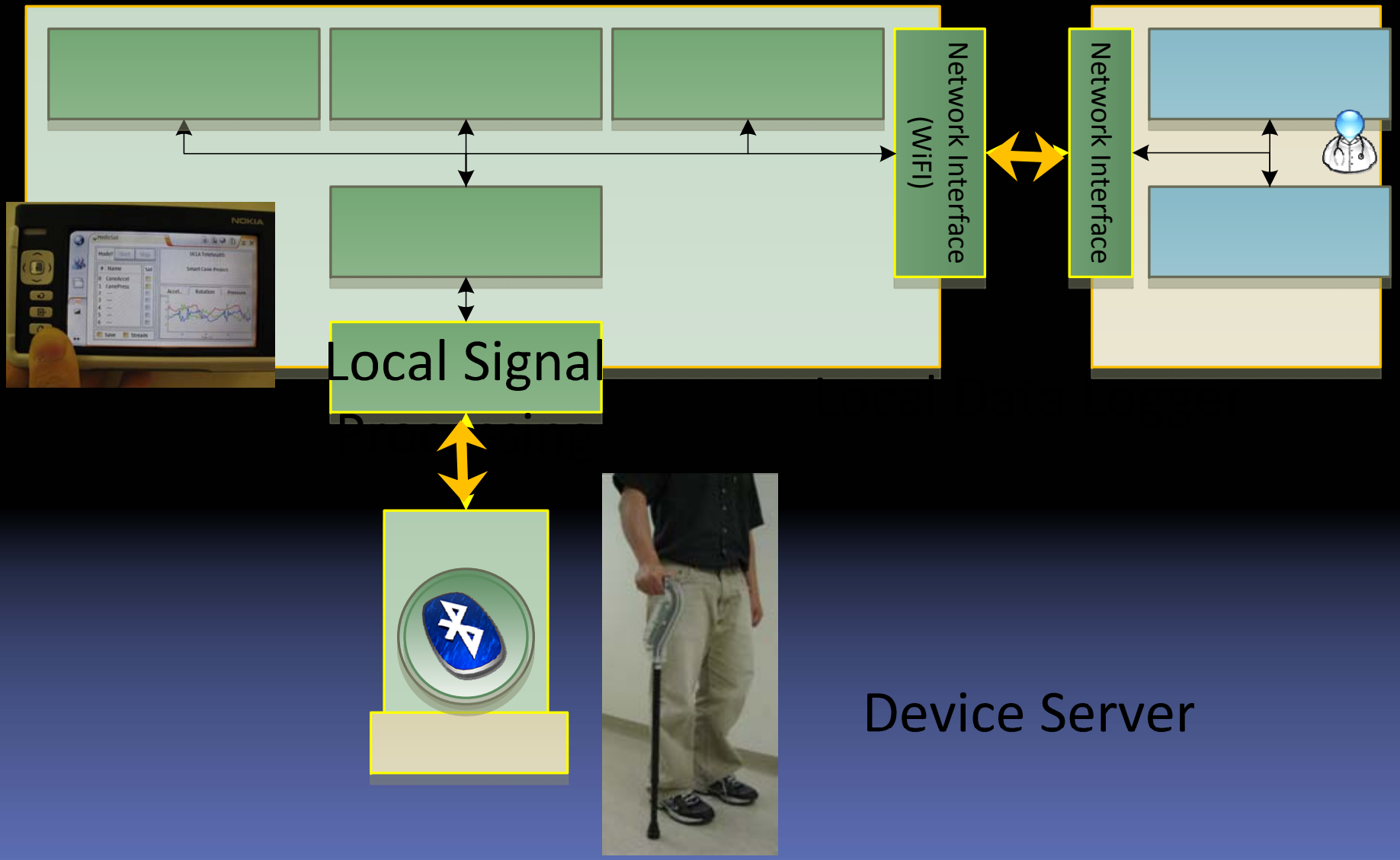


- Sensing
  - 3-Dimenstional acceleration and orientation
  - 3-Dimensional rotation
  - forces
    - handle grip
    - tip downward

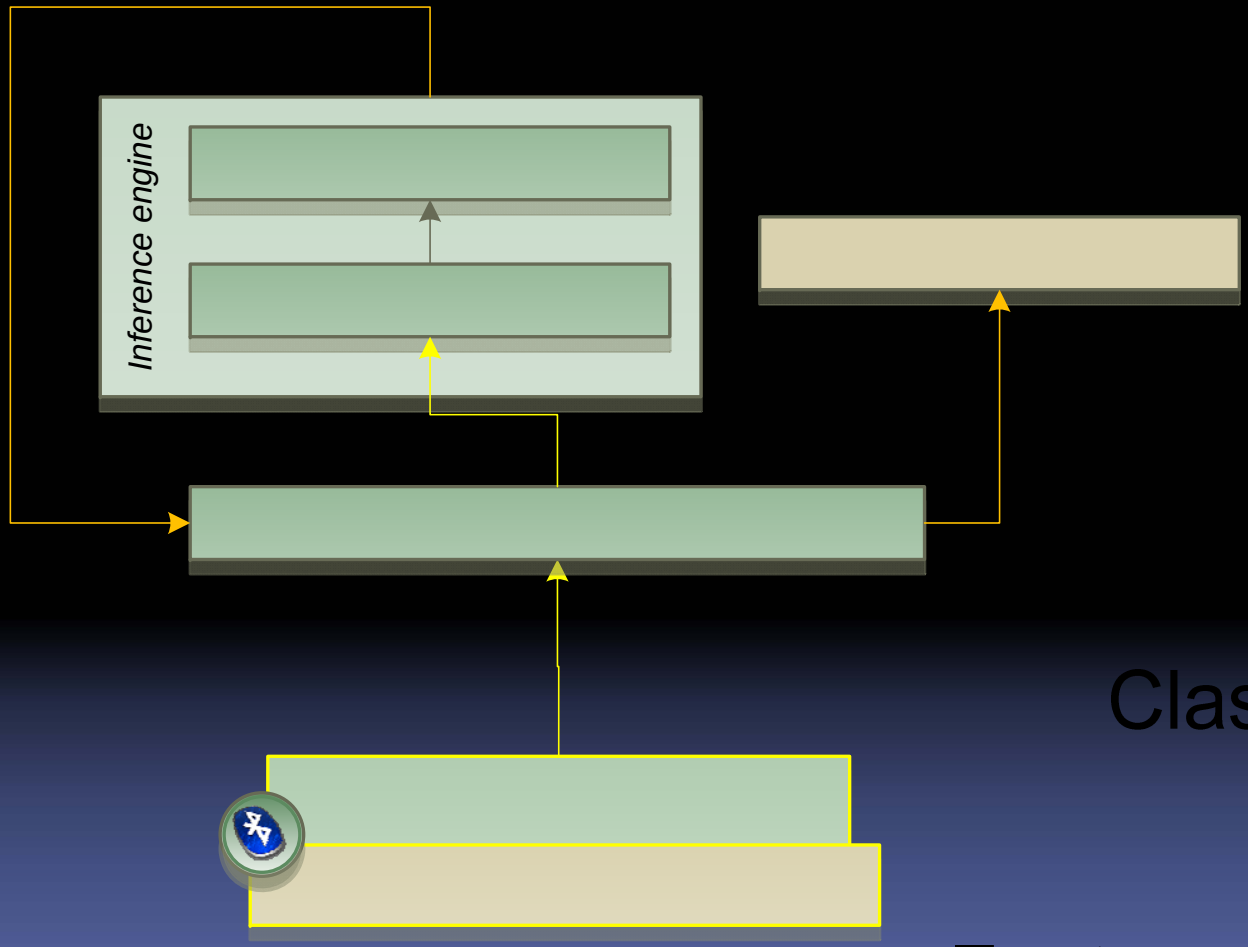
MicroLEAP Wireless Sensor Node

- 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



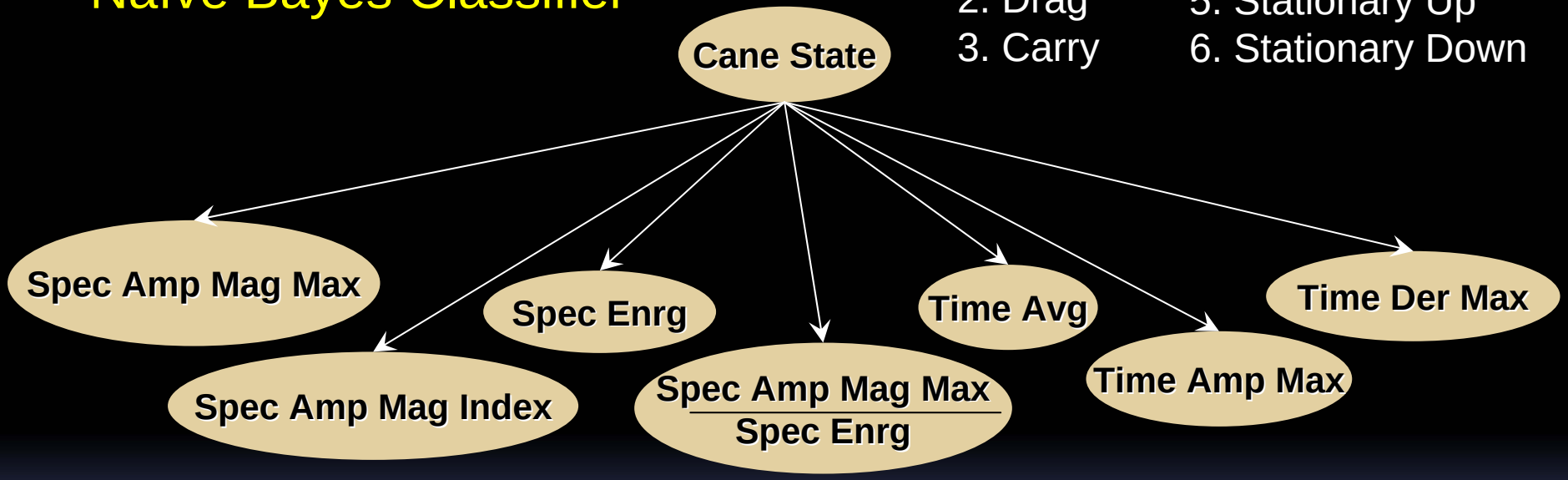
Local Signal Processing



Inference Engine

Naïve Bayes Classifier

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

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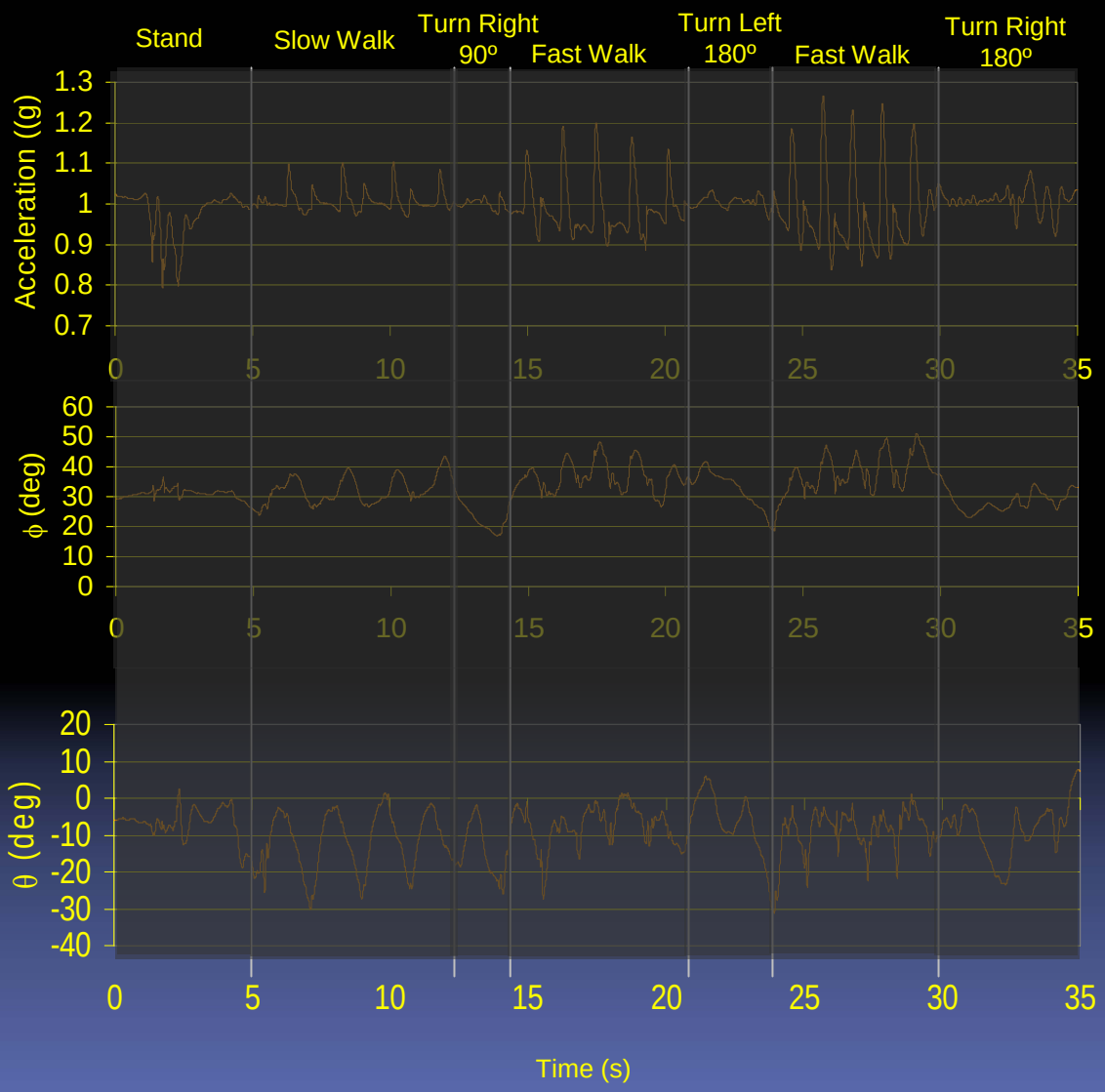
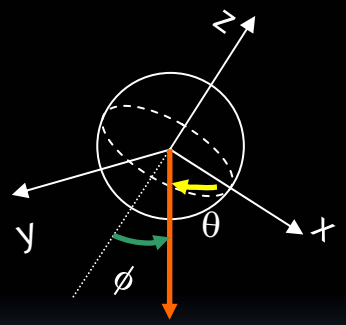
Accelerometer Data





ρ = magnitude of acceleration

ϕ = tilt angle from vertical axis

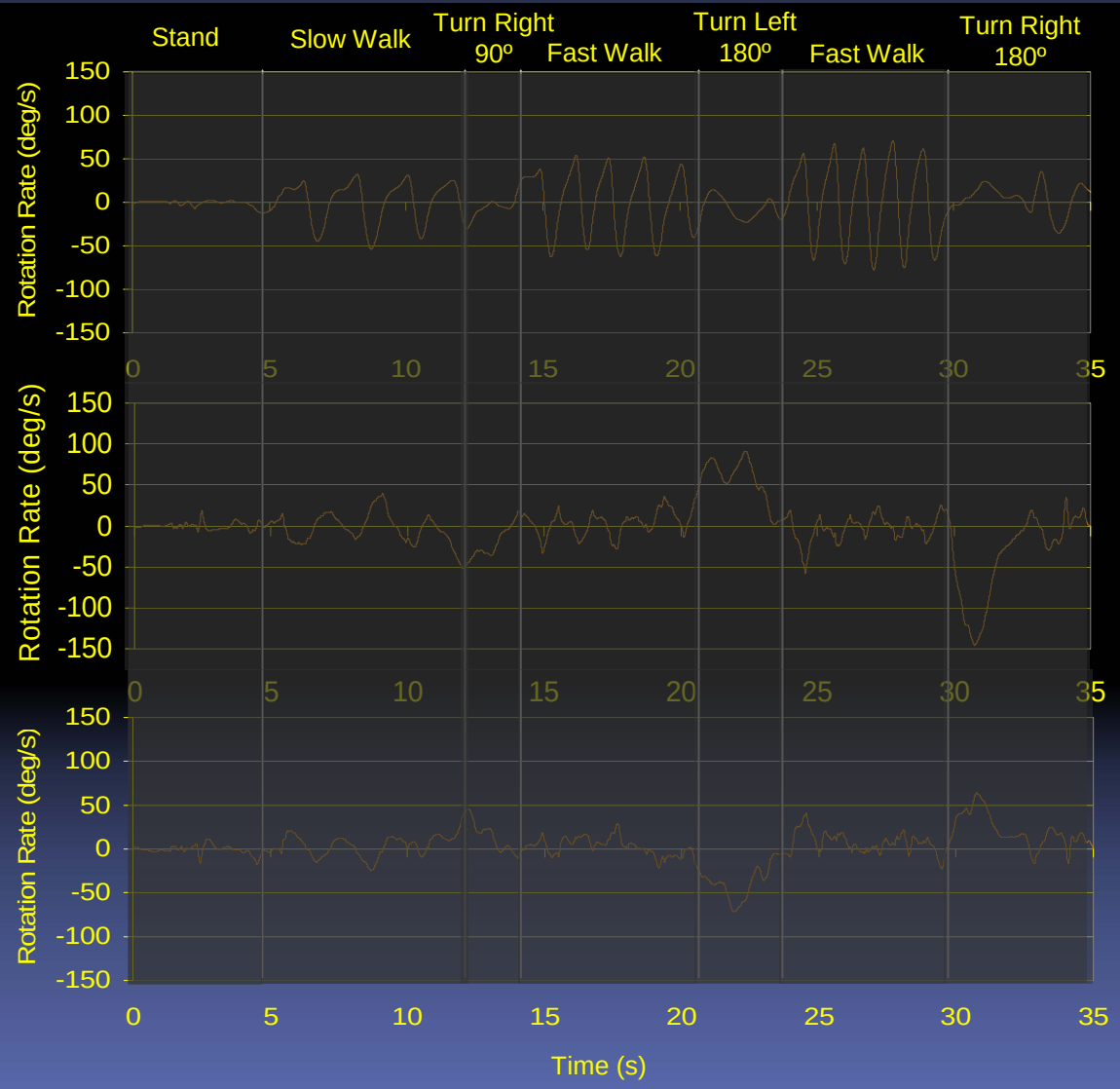
θ = tilt angle on side

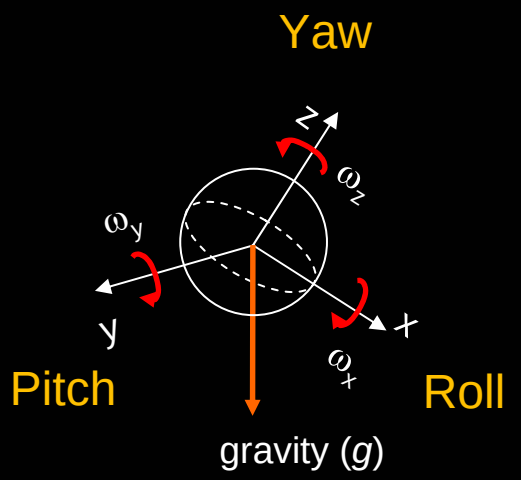
Gyroscope Data

ω_y Pitch

ω_z Yaw

ω_x Roll





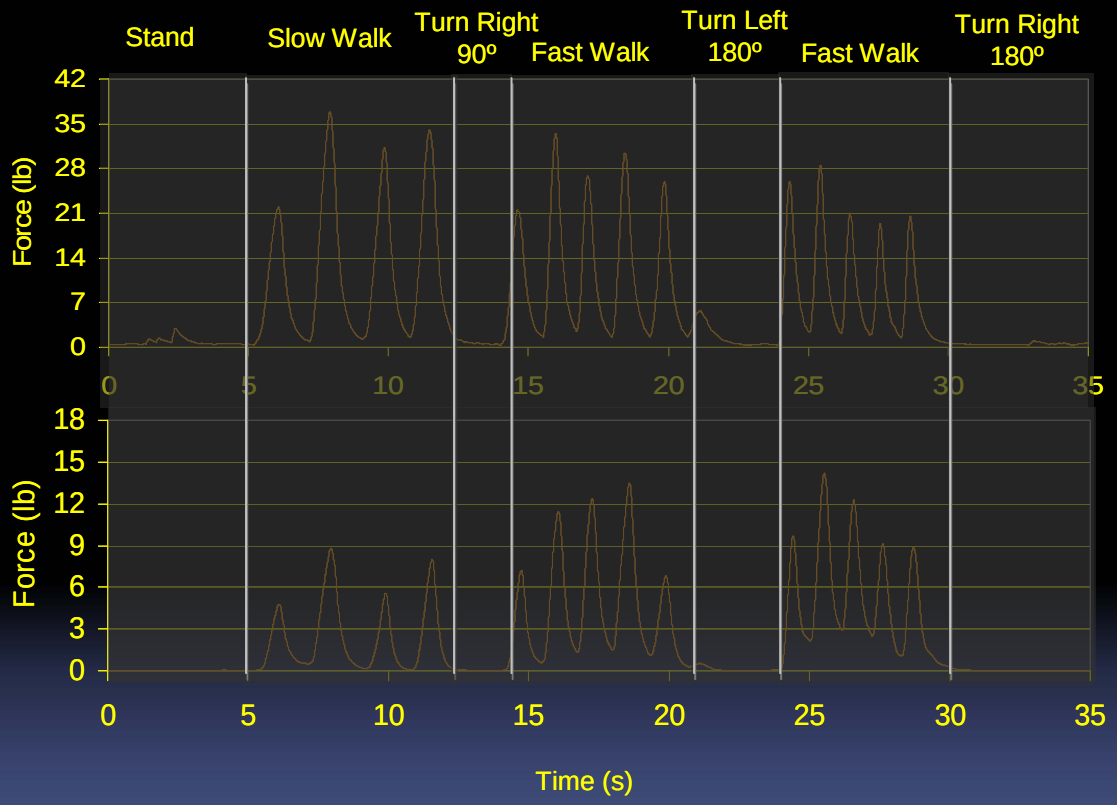
Pitch = swing rate of the cane

Yaw & Roll detect the turns

Pressure Sensor Data

Tip

Handle



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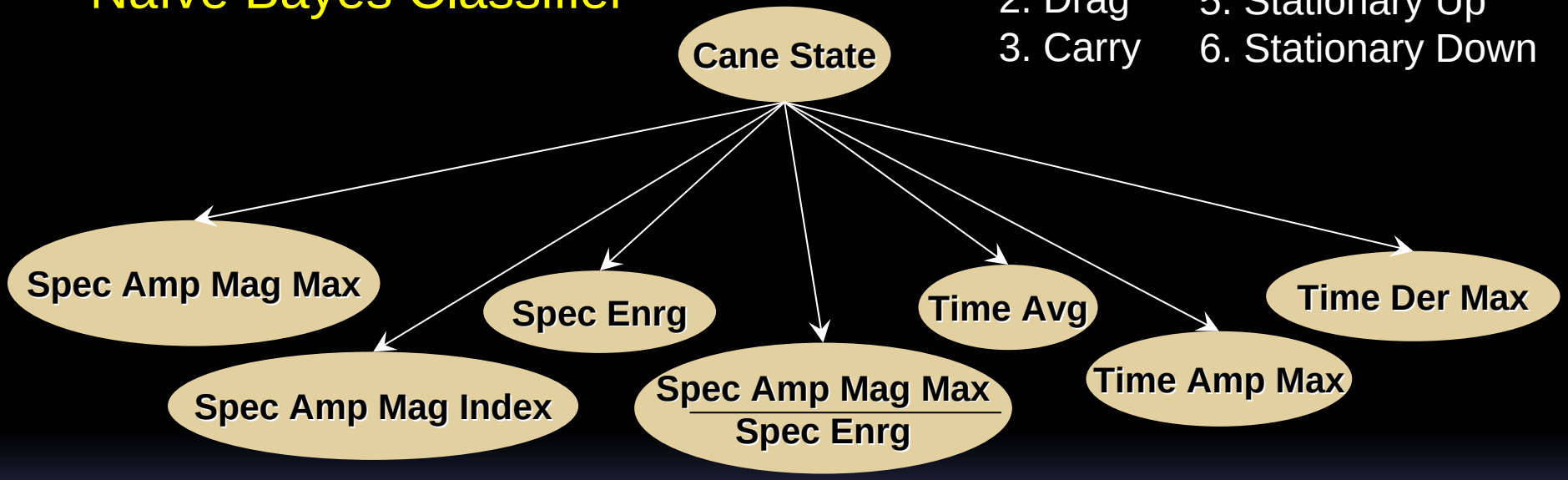

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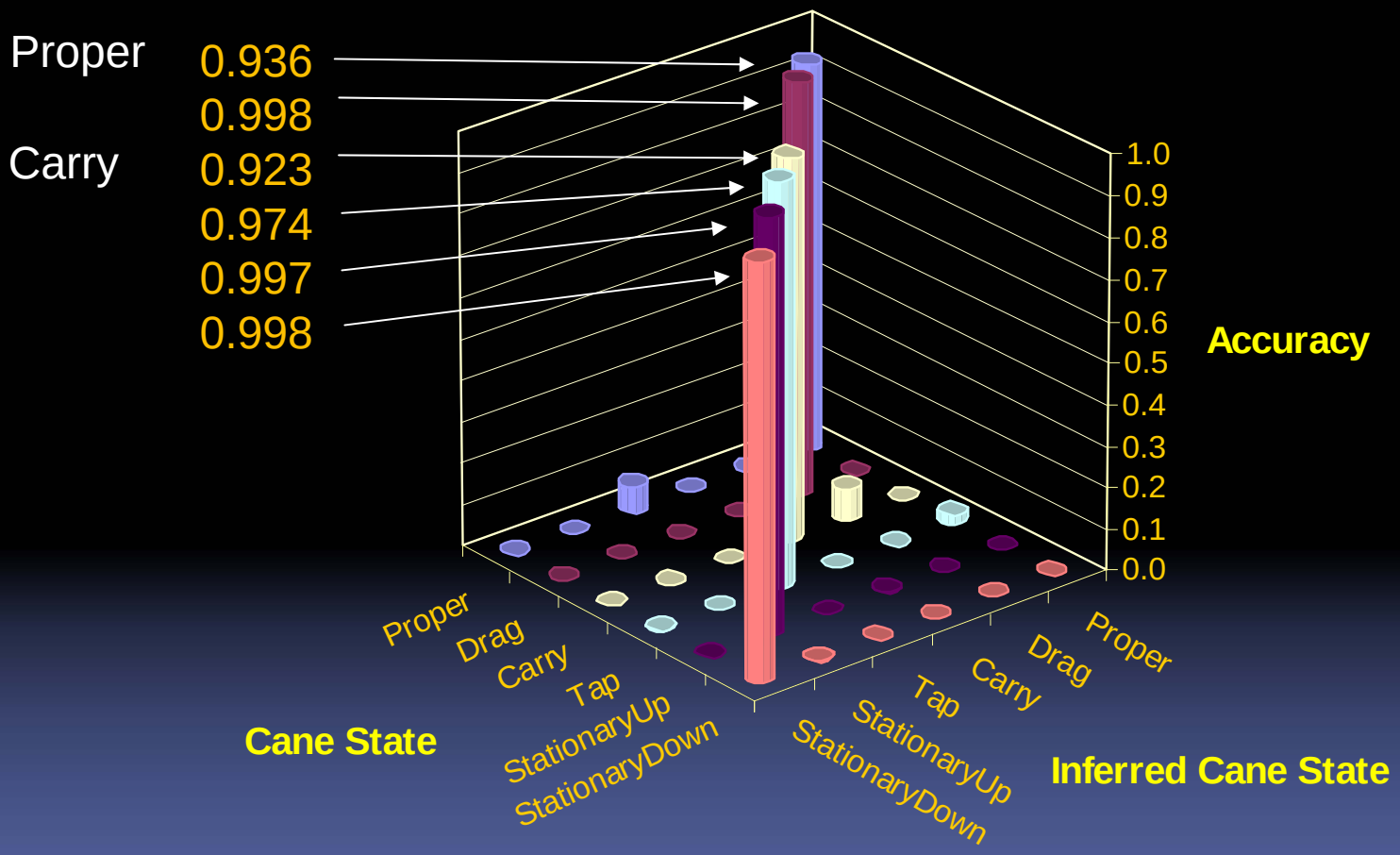
Inferred Cane State Accuracy



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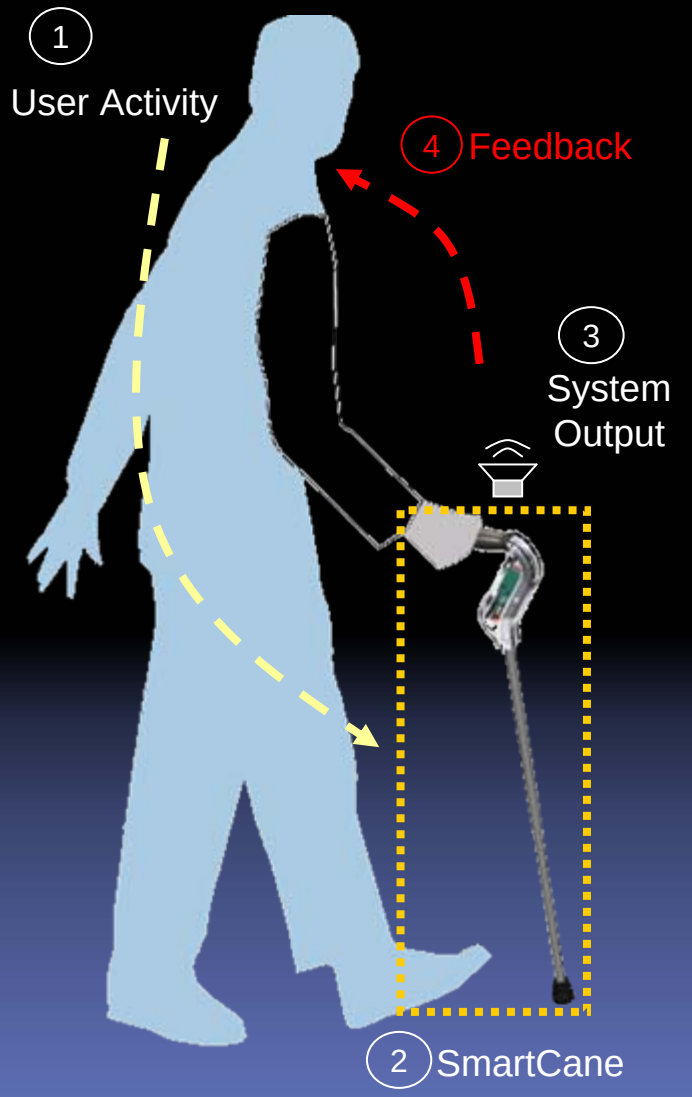
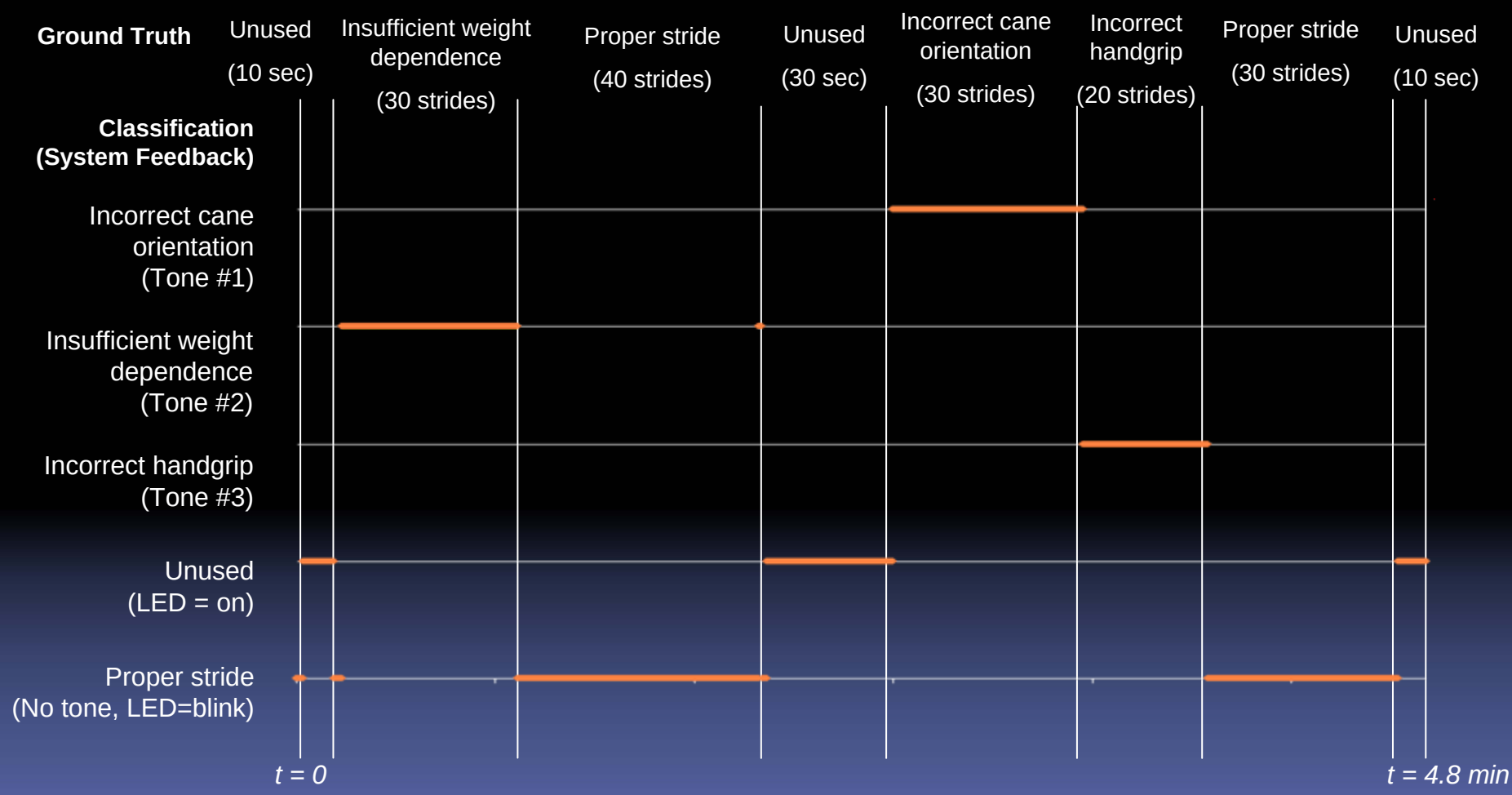
Current Activity: Patient Feedback

- Provide patient feedback by means of
  - Voice
  - Vibration
  - Acoustic tones
    - Tap
    - Loose grip
    - Hold side way

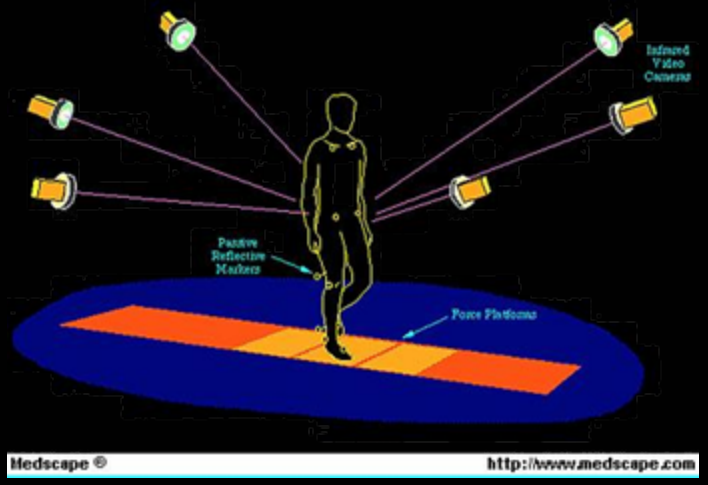


Patient Feedback



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.