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

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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 \(^3\).

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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

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Modular algorithms and device reconfiguration

Sensor records and events

Medical enterprise

Tier 3
BAN/PAN

Tier 2
WLAN (WiFi/GPRS)

Tier 1
Network Infrastructure

Home

SmartCane System

Medical enterprise

Healthcare provider

Network Infrastructure

Sensor records and events

Modular algorithms and device reconfiguration

Tier 3
BAN/PAN

Tier 2
WLAN (WiFi/GPRS)

Tier 1
Network Infrastructure

SmartCane System

Home
The SmartCane System

- Contact pressure sensor
- 1 x 3-axis accelerometer
- 3 x single-axis gyros
- MicroLEAP
- Bluetooth

### 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/](http://cvs.cens.ucla.edu/viewvc/viewvc.cgi/leap/)
Software Architecture

[Diagram showing network interfaces and connectivity]

Local Signal

Network Interface (WIFI)

Network Interface

Bluesooth Serial

Device Server

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Local Signal Processing

Inference engine

Classifier

Feature extraction
7 features are extracted from each sensor channel consisting of:

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

Naïve Bayes Classifier

Cane State

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

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

gravity (g)
Gyroscope Data

- $\omega_y$: Pitch
- $\omega_z$: Yaw
- $\omega_x$: Roll

Yaw = swing rate of the cane

Pitch and Roll detect the turns

Rotation Rate (deg/s) vs. Time (s)
Pressure Sensor Data

- Stand
- Slow Walk
- Turn Right 90°
- Fast Walk
- Turn Left 180°
- Fast Walk
- Turn Right 180°

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</table>

- Tip
- Handle
7 features are extracted from each sensor channel consisting of:

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Current Activity: Patient Feedback

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

1. User Activity
2. SmartCane
3. System Output
4. Feedback
Patient Feedback

Ground Truth

Unused (10 sec)

Insufficient weight dependence (30 strides)

Proper stride (40 strides)

Unused (30 sec)

Incorrect cane orientation (30 strides)

Incorrect handgrip (20 strides)

Proper stride (30 strides)

Unused (10 sec)

Classification (System Feedback)

Incorrect cane orientation (Tone #1)

Insufficient weight dependence (Tone #2)

Incorrect handgrip (Tone #3)

Unused (LED = on)

Proper stride (No tone, LED=blink)

$t = 0$

$t = 4.8$ min

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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.