Motion-sensing Devices in the Assistive Technology Arena

Owen R. Edwards, MEng

Rehabilitation Engineering Research Fellow,
Smith-Kettlewell Eye Research Institute
& Bioengineer, Stanford University School of Medicine

Introduction

- Emerging technologies for Rehab & Assistive Tech.
  - MEMS devices
- Touch screen device accessibility
  - Braille & the “WearaBraille”
- Wearable Gait Analysis

Emerging technologies

- Users are increasingly tech-savvy
  - Less intimidated by technology
  - Expect access to new devices
- Rehab and A.T. can leverage technologies from:
  - Consumer Electronics
  - Mobile Devices
  - Game Consoles

MEMS sensors

- “Micro-Electro-Mechanical Systems”
- Semiconductor devices, combine:
  - mechanical sensor structure
  - electronic measuring and signal processing circuits
- Accelerometers, Gyroscopes, Magnetometers
- Used in Wii Remote, Apple iPhone, digital cameras

Accelerometers

- Accelerometers measure:
  - Static orientation relative to gravity

  - Linear acceleration / movement

Gyros and Magnetometers

- Gyroscopes measure rate of rotation:
  - Wii MotionPlus accessory

- Magnetometers measure orientation relative to Earth’s magnetic field:
  - iPhone 3G S

Touch screens:

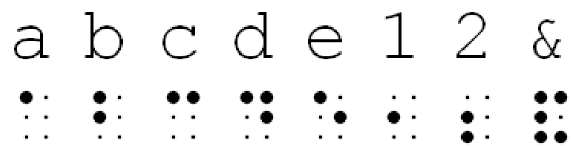
a barrier to accessibility?

Touch screens

- Portable devices increasingly use touch screens as the main user interface
- Touch screens are difficult for:
  - Blind & visually impaired users
  - Physically impaired users
  - Use while driving?!
- Auditory (TTS) output options, but Speech Recognition has limitations
- Are there <u>other</u> options for <u>input</u> to the device?

Intro to Braille

- Standard Braille cell is 6 dots:



- All information is <u>on the edge</u> of the cell
- Different Braille alphabets
  - Standard English (has “number sign”, abbreviations “th”, “ed” etc.)
  - Computer Braille (letters and numbers are distinct)
- A form of “printing”, i.e. an “<u>output</u>” technology?

Braille typing: The Perkins Brailler

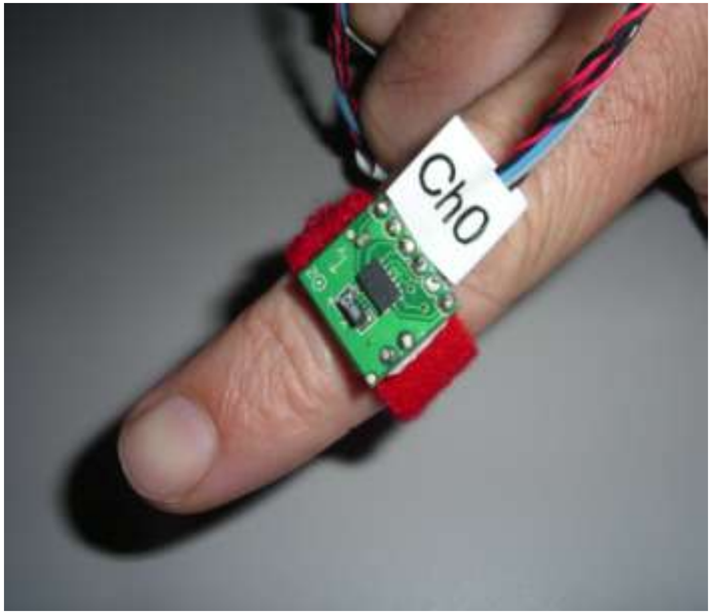
- A Braille typewriter
- Direct entry of Braille
  - a key for each "dot"; hence "chording"
  - space, linefeed, backspace
- Heavy!
- An existing interface paradigm

Touch Graphics “Power Chord”

- Same 9 keys
- USB interface to PC
- No special software drivers
- Extended “chord” combinations for:
  - Cursor movement
  - CTRL-ch, ALT-ch combinations

Can we “type” without a keyboard?

- Finger-mounted accelerometer:
  - Small
  - Low-cost
  - Low-power
  - 3D, 8G, 400Hz sampling
  - How does the physical interface affect the accelerations?



- Could we detect typing on any available firm surface?

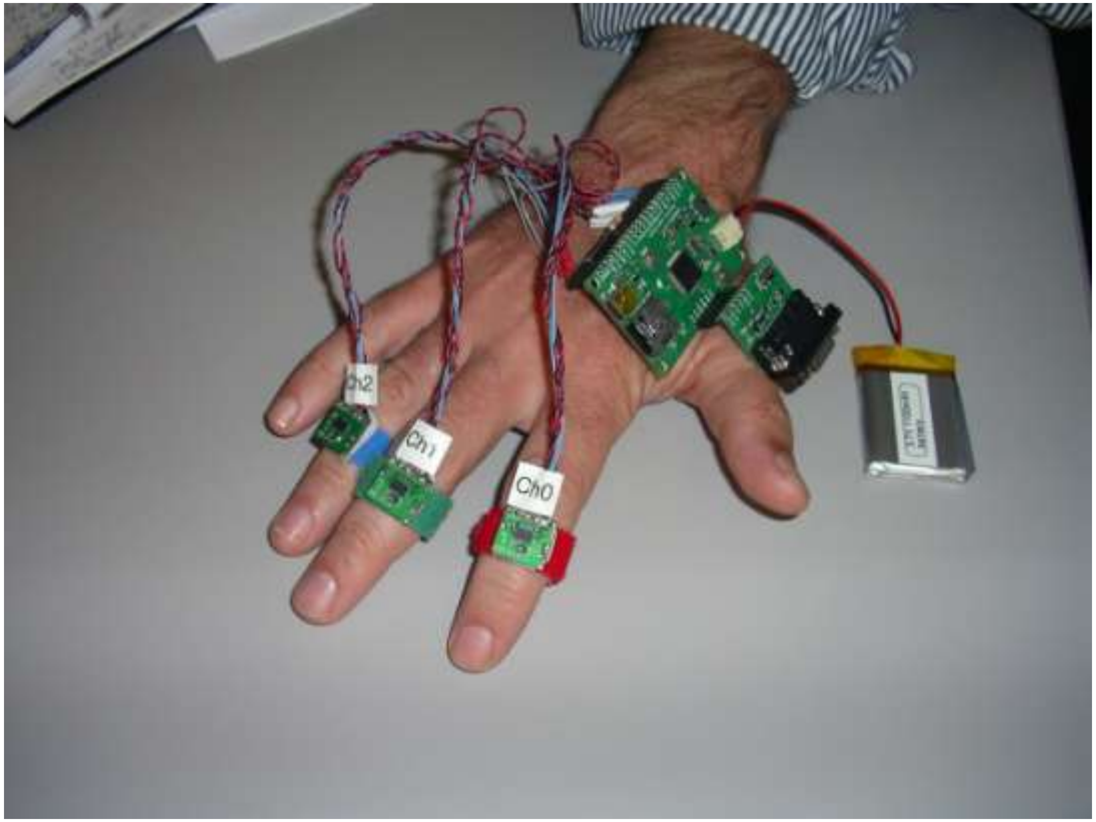
“Tap” detection & discrimination

- Braille keyboard has <u>only one key per finger</u>
- Absolute magnitude of 3D acceleration vector is <u>not</u> a good discriminator
- “Tap” characterized by rapid <u>change</u> in acceleration, especially change in direction of acceleration
- Derivative of acceleration (“jerk”) could be used
- “Dot product” of successive acceleration vectors gives a scalar measure of direction change

“Taps” to “chords”

- All chording keyboards need to combine keypresses
- Difficult to detect “key up” (un-tap?) event
- Combine several “taps” into a “chord” by using a time window
  - Average typing of 60 WPM = 5 characters / second
  - World record for typing is 150 WPM = 12.5 characters / second
  - A fixed window of 50-100 mS works, but an adaptive scheme is better

WearaBraille one-hand prototype



USB keyboard emulation

- Human Interface Device (HID) class of USB device
- Well-defined protocol for PC connection:
  - No special device drivers
  - WearaBraille appears as “just another keyboard”
- Extensible as a “composite device”:
  - Both a keyboard …
  - … <u>and</u> a “special control device” (joystick, game controller, etc)
- USB supplies power for WearaBraille
- Phones and PDAs often don’t have USB

Two-handed operation

- Need to integrate "taps" between hands
- Need low-latency communication between hands
- Ideally a wireless link
- 10 fingers & thumbs -> 10 key operation: additional "chords" possible with independent thumb operation

Communication between hands

- Several new low-power wireless communication protocols:
  - Zigbee
  - ANT
  - Bluetooth
  - Wireless USB (aka “UWB”)
- Choice of system architecture (division of processing, communication with PC/PDA/phone)
- Many portable devices support Bluetooth
- Need batteries to power WearaBraille

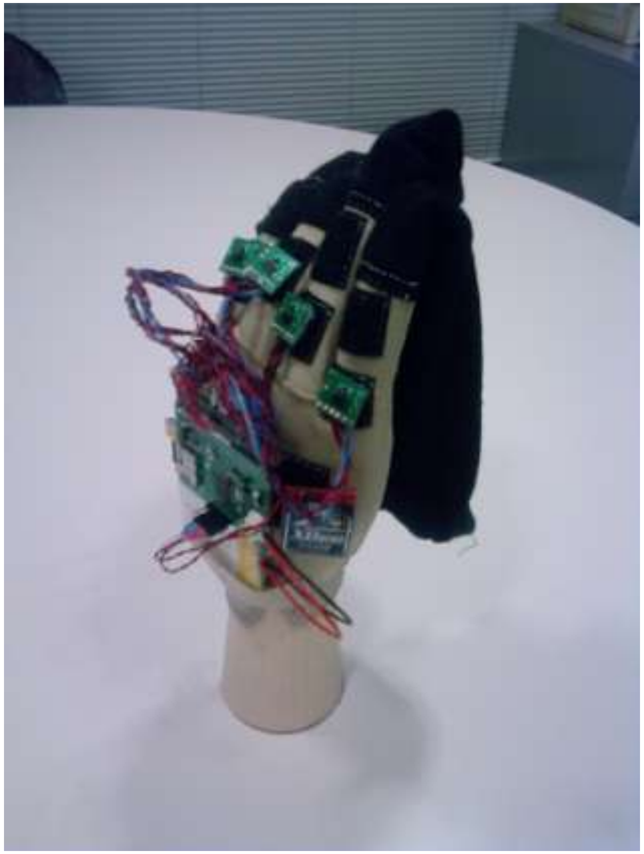
Zigbee (IEEE 802.15.4)

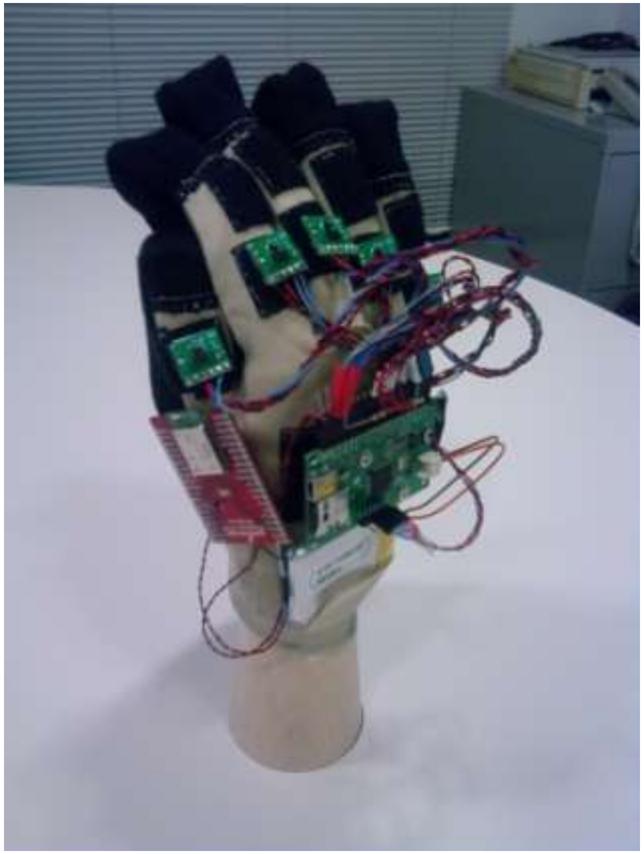
- Low-power, low-complexity, low-cost wireless for “monitoring & control”
- Peer-to-peer, automatic networking
- Typically “serial port replacement”
- Power/range trade-off options:
  - Standard : 130mW / 400 ft (133 ft indoor)
  - PRO: 970mW / 1 mile (300 ft indoor)

Bluetooth

- Short-range “cable replacement” personal area network (“PAN”)
- Profiles
  - Headset Profile (HSP)
  - Hands-Free Profile (HFP)
  - Advanced Audio Distribution Profile (A2DP)
  - <u>Human Interface Device Profile (HID)</u>
  - FTP, DUN, SPP, OPP, BPP etc…
  - Health Device Profile (HDP)
- <u>Not all devices support all profiles</u>
- Bluetooth Low Energy (“more than a year on a button cell battery”)

Two-handed WearaBraille prototype





Other considerations for WearaBraille

- “On” / “Off” sequence -> “Wearability”
- User feedback (auditory, tactile)
  - Local (on the gloves)
  - Remote (PC / PDA)
- Glove construction & mechanical interface
- User training / WearaBraille “learning”
- Battery life & low-power operation
- Interface to devices that do not support Bluetooth HID profile

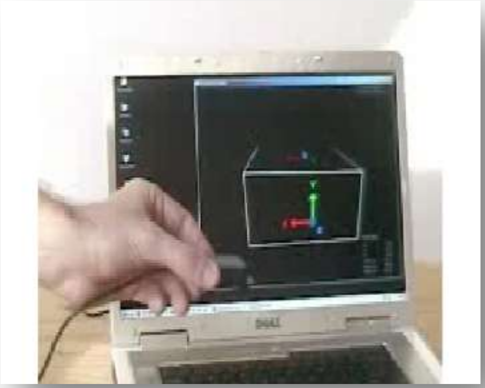
Wearable Gait Analysis

Wearable sensors for motion capture (vs. optical system)

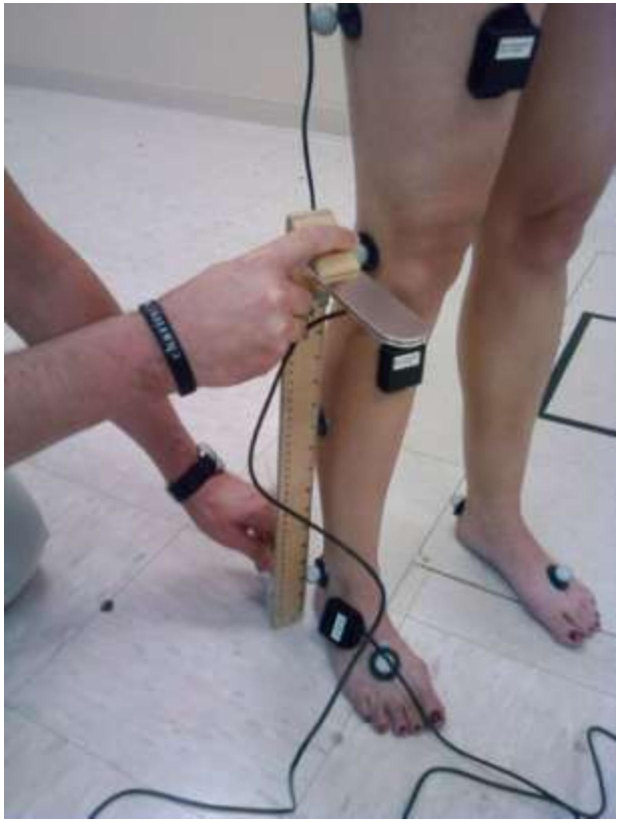
- Used in the entertainment industry:
  - Movies
  - Video games
- Each sensor combines:
  - A MEMS Accelerometer
  - A MEMS Gyro
  - (sometimes) A MEMS Magnetometer
- Compared to traditional optical motion capture:
  - ✓ Larger “capture space”
  - ✓ Occlusion-free
  - ✗ Less accurate
  - ✗ Subject to drift

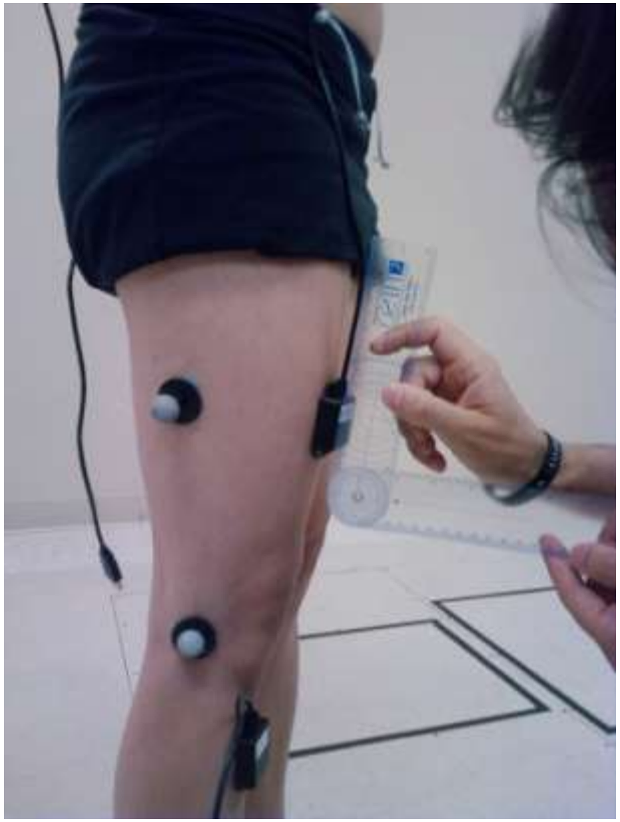
MotionNode sensors

- Combine MEMS Accelerometer, Gyroscope, Magnetometer
- Small, lightweight package
- Easy connection to PC via USB
- 'Service' process on PC (Windows or Linux) calculates absolute orientation from sensor data
- Comprehensive Software Development Kit (SDK) supports C++, Matlab, Python etc.



MotionNode sensors compared to optoelectrical 3D gait analysis





Using the MotionNode data

- MotionNode software outputs:
  - Raw sensor data
  - Calculated orientation of the device
- From this, we can derive:
  - Repetition rate
    - gait cycle duration
  - Significant events, separated by cycle duration
    - initial contact with the floor
  - Relative orientation of sensors
    - knee & ankle flexion through gait cycle

Potential applications

- Gait analysis in a “community setting”
- Detect gait abnormalities <u>as they happen</u>
- “Functional Electrical Stimulation” (FES) for improvement of gait abnormalities

Summary

- New technologies can be “re-purposed” into A.T. & rehab devices
- MEMS and wireless technologies show promise
- Plenty of “needs”, but obstacles include:
  - Cost
  - Small potential market
  - Hard to make anything “general purpose” -> smaller market