CS 525M Mobile and Ubiquitous Computing

Using Mobile Phones to Write in Air

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Who and Where?

- Systems Networking Research Group
  Duke University, Durham, NC, 2009 - 2011

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Introduction/motivation:
What was the main problem addressed?

- MOTIVATION:
  - Phones and sensors allow for people-centric apps. Can write in the air.
- MAIN POBLEM:
  - Alternative input method using accelerometer for text and drawing by writing in the air – use mobile phone to write in the air

Introduction/motivation:
What was the main problem addressed?

- WHY IMPORTANT:
  - Assistive technology - Allow people with disabilities to use
  - Don’t have to type, frees your other hand and your eyes to watch what’s around you.
  - Writing English alphabets/words in real-time with commodity phones has been an unexplored problem.
  - http://www.youtube.com/watch?v=Nvu2hwMFkMs

Introduction/motivation:
Why is this problem solved important?

- VISION:
  - PhonePoint Pen (P3) establishes feasibility and justifies longer-term research commitment
  - Write short messages, draw simple diagrams
- Use cases
  - Assistive technology for impaired patients
  - Equations and sketching
  - Emergency operations and first responders
  - Write message on top of picture

Related Work:
Air-gestures with 3D accelerometers

- Sensor/custom hardware – pattern matching, no pen reposition, continuous
- uWave - detection of 8 gestures, 99% accurate, no character recognition
- P3 – has individual stroke grammar, character transition

Related Work:
Vision based gesture recognition

- Use cameras to track object’s 3D movements
- TinyMotion
  - Uses built-in cell phone camera to detect simple movements.
  - No character or word detection.
- Microsoft Research TechFest: Write in The Air (2009)
  - Character, but no word detection.
  - http://www.youtube.com/watch?v=WmiGtt0v9CE

Related Work:
Stylus-based sketch recognition

- Draw sketches on a pad or Tablet PC using a stylus
  - SketchREAD
  - Electronic Cocktail Napkin
  - Unistrokes - single-stroke characters
  - Graffiti - single-stroke characters
- Pen-touch based Tablet PCs
  - Can relocate pen
  - Visual reference
- Samsung Galaxy Note (5”, 8”, 10”)

Related Work:
Wiimote, Logitech Air-Mouse, Nokia NiiMe

- Nintendo Wii, PlayStation Move, Xbox Kinect
  - track hand gestures, good accuracy
  - accelerometer
  - gyroscope (hand rotation)
  - digital camera and LED orb
- Consumer phones with gyroscopes – solve challenges rotation and stroke detection.
- Logitech Air Mouse, NiiMe

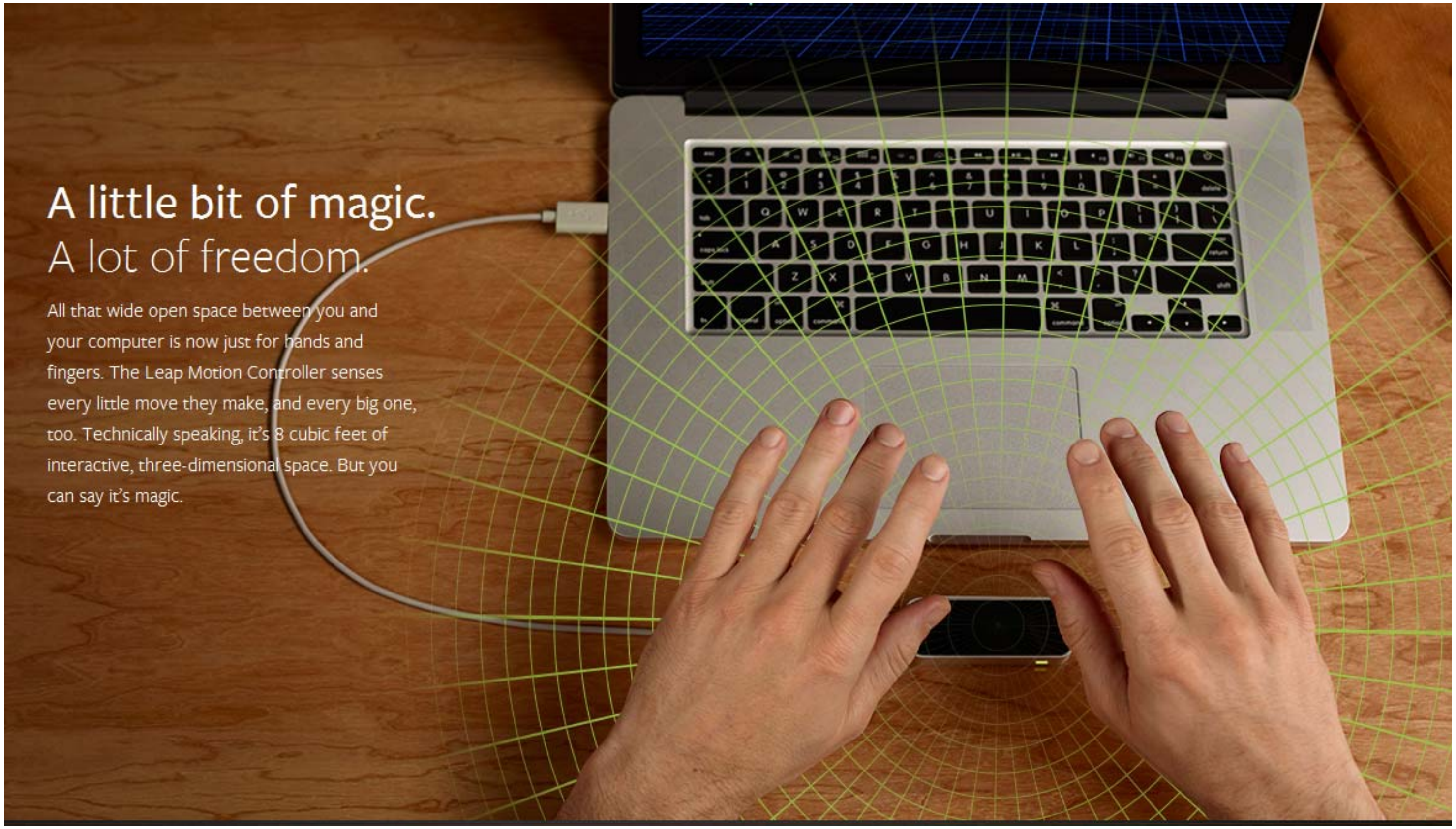
Related Work:

Related Work:
Smart Pen and SmartQuill

- Livescribe Smartpen
  - pen-like device track person's writing
  - requires a special dotted paper
- SmartQuill
  - pen device recognize handwriting
  - any surface (including air), significant training
- PhonePoint Pen
  - does not rely on special hardware or paper, and does not require training.

Related Work:
Leap Motion Controller

Senses individual hand and finger movements



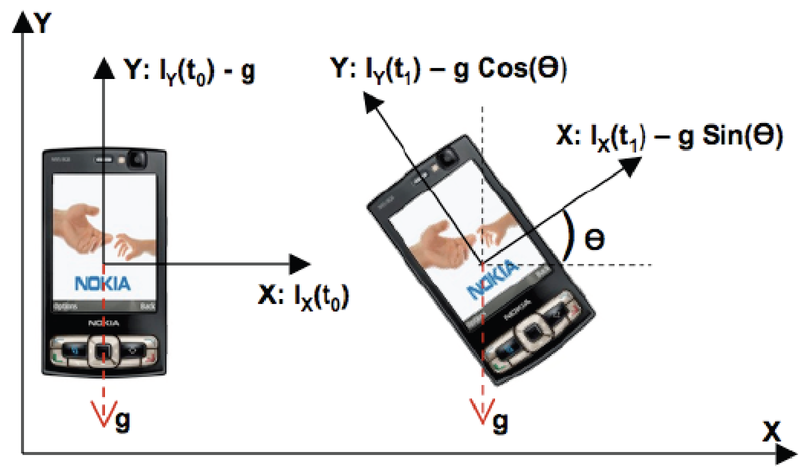
Methodology:
Overview/Summary of approach/design

- Nokia N95 phone (2007)
- Symbian OS
- Experiments with
  - 10 CS and Engineering students
    - Novice (<10 chars)
    - Trained (>26 chars)
  - 5 patients from Duke University Hospital

Methodology:
Core Challenges – Rotation Gyroscope

ISSUE:

- Nokia N95: cannot detect rotation
  3-axis accelerometer X, Y, Z, no gyroscope
- Can’t tell difference between linear movements and rotation using just the accelerometer.



Methodology:
Core Challenges – Rotation Gyroscope

APPROACH:

- Hold like pen or blackboard eraser
- Pause between strokes

Pretending the phone's corner to be the pen-tip reduces rotation.

Methodology:
Core Challenges - Background Vibration

ISSUE:

- Jitter from natural hand vibrations
- Measurement errors from accelerometer

APPROACH:

- Noise-reduction
  - Smooth with moving average over last 7 readings
  - Drop data under threshold, <= **0.5m/s²** = noise

Methodology:
Core Challenges – Computing Displacement

ISSUE:

- Phone movement can introduce errors as integrating from Acceleration to velocity to displacement.

APPROACH:

- Reset velocity to zero if previous accelerometer readings below threshold (noise)

Methodology:
Core Challenges – “A” v. Triangle

ISSUE:

/ + \ + —— = A … or a triangle?

APPROACH:

- Watch for “lifting of the pen”
- Monitor data, but don’t include in final output

Methodology:

Core Challenges – Character Transitions

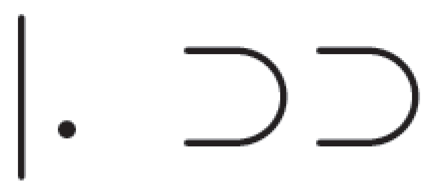
ISSUE:

- Can’t tell difference between B and 13 same set gestures cause ambiguities

APPROACH:

- Use delimiter between characters – dot or pause

B = 

13 = 

Methodology:
Gesture Stroke Detection primitives

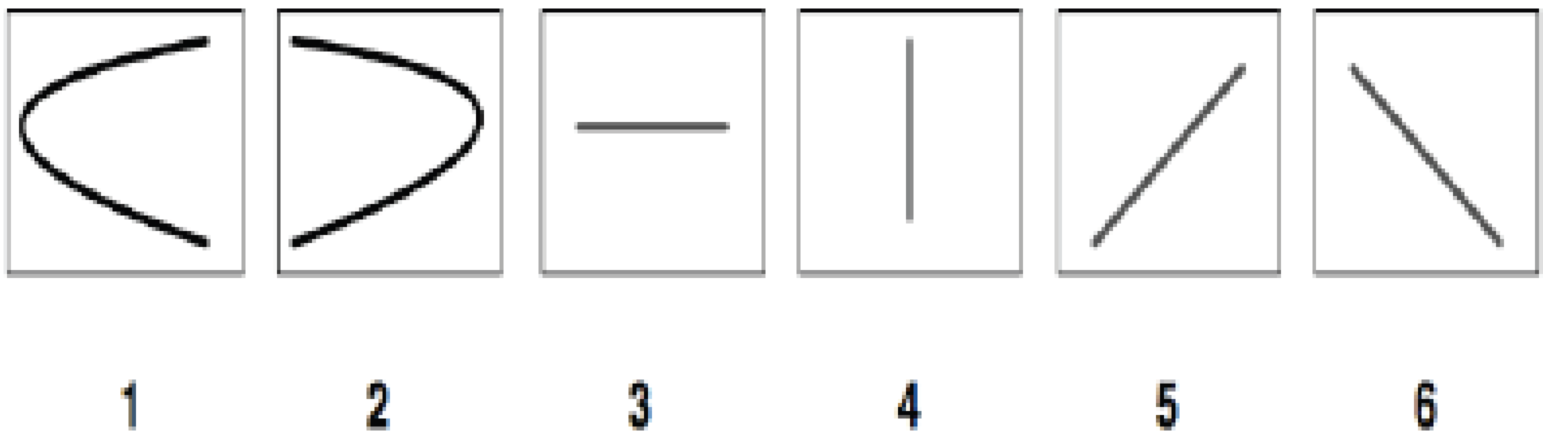


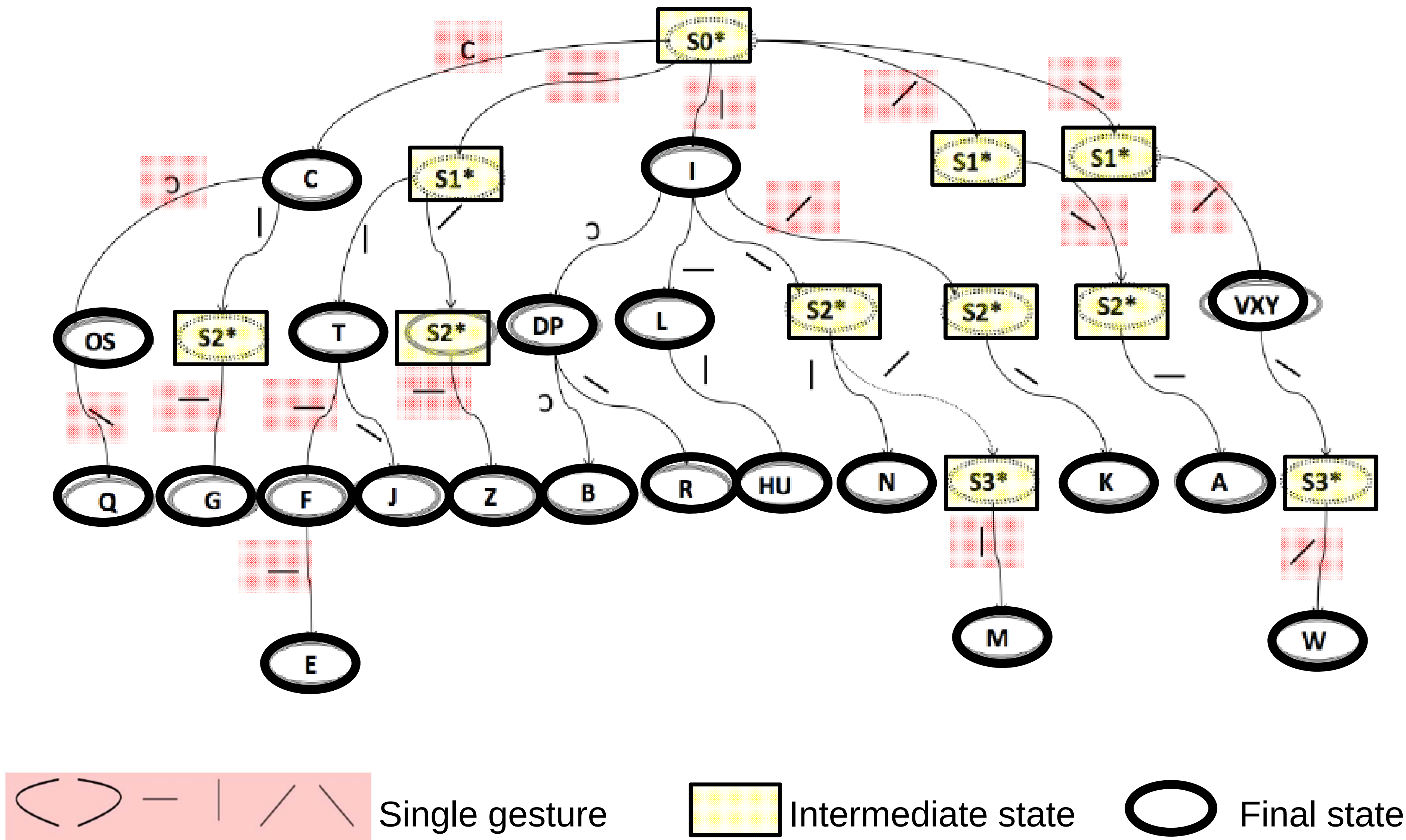
Figure 4: Basic strokes for English characters.

Methodology:
Character Recognition

- Stroke grammar using decision tree
- D and P - start same, but then can turn into N
- O and S – same strokes
- X and Y – same strokes
- O and 0 – cannot tell difference

Methodology:

Stroke grammar for English alphabets and digits



Methodology:
Word Recognition

- Examples: B and 13, H and IT
- Look at sequence of previous and next strokes
- Infer previous character when see start of new char
- Watch for move back to left position
- Have user pause or draw dot to delimit characters

Methodology:
P3-Aware Spelling Correction

- Distance for correction (replace # chars)
- MQM edit distance of 1 with MOM, MAM, MUM.
  - P3 confuses Q with O but hardly confuses Q with A or U, can suggest MOM with high confidence.
- NIET – could be NET or MET
  - Edit distances of 1 and 2,
  - P3 confuses “M” as “NI” > probability than “E” as “IE”. could predict user intended MET with reasonably high probability

Methodology:
P3-Aware Spelling Correction

Probability of valid word i

$$\phi_w = \{i : \frac{P(w|i)}{P(w|j)} > 1\} \ \forall \ valid\ words, i, j, i \neq j$$

Corrected word

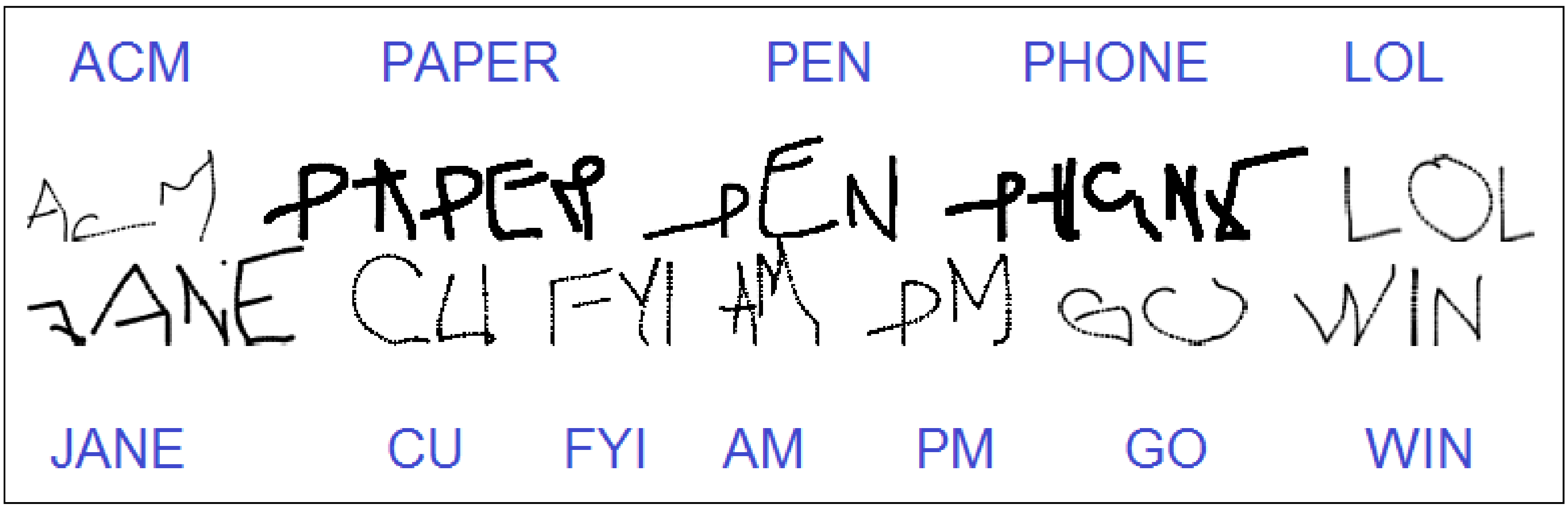
Probability of valid word j

Methodology:
Assumptions and limitations of this work

- Speed of writing = 3:02 sec/letter on average
- Repositioning pen for long words and drawing
- Cursive handwriting (continuous movement)
- Can't write AND move at same time
- Users were CS majors, but can train others
- Investigate "greater algorithmic sophistication" for gesture recognition (Bayesian Networks and Hidden Markov Models)

Results:

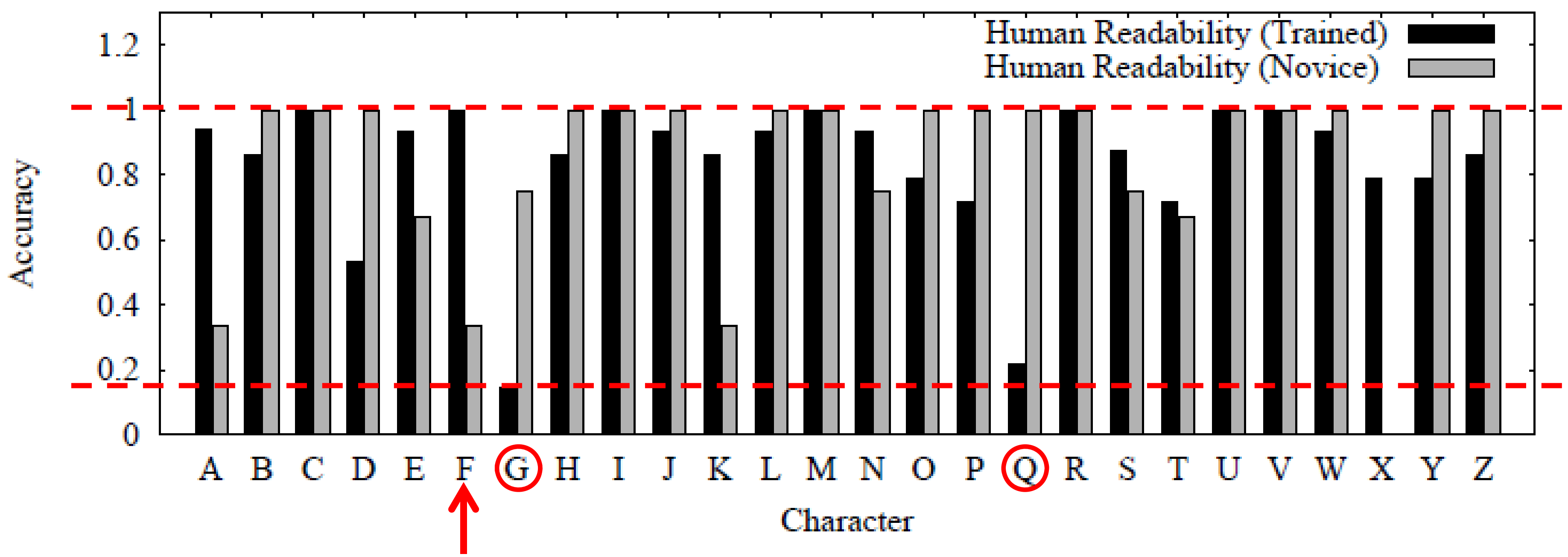
- English characters identified with average accuracy of 91:9% … but
- Slow: speed = 3.02 sec



Results:
Human Readability Accuracy (HRA)

Average readability

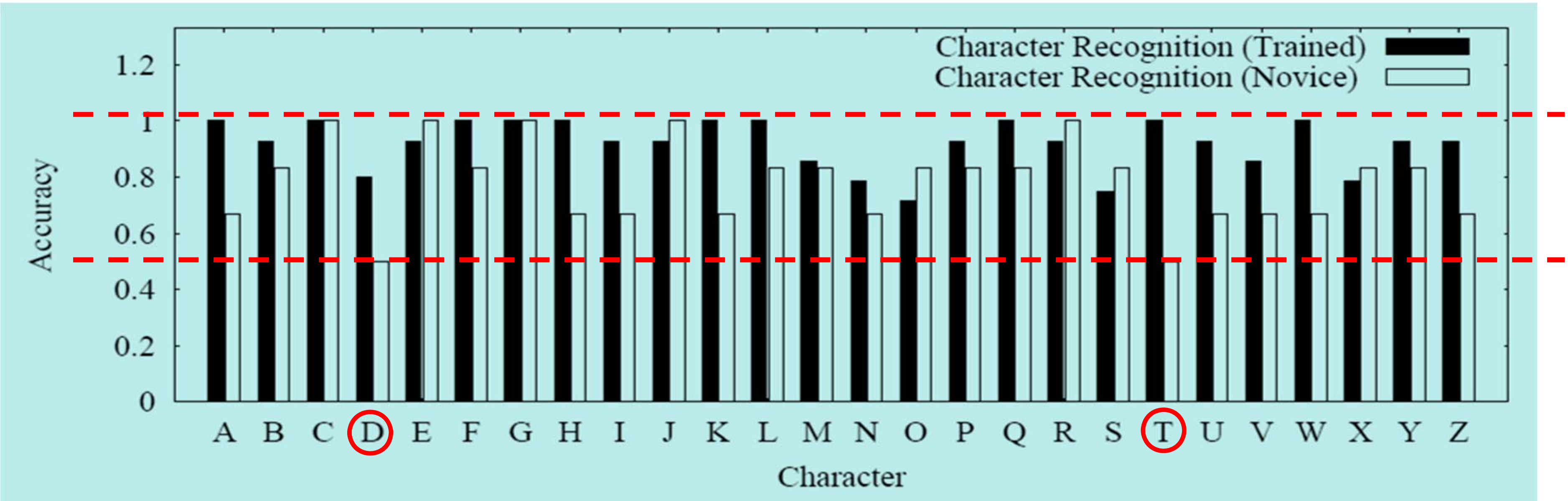
- Trained writers: 83%
- Novice writers: 85:4%



Results:
Character Recognition Accuracy (CRA)

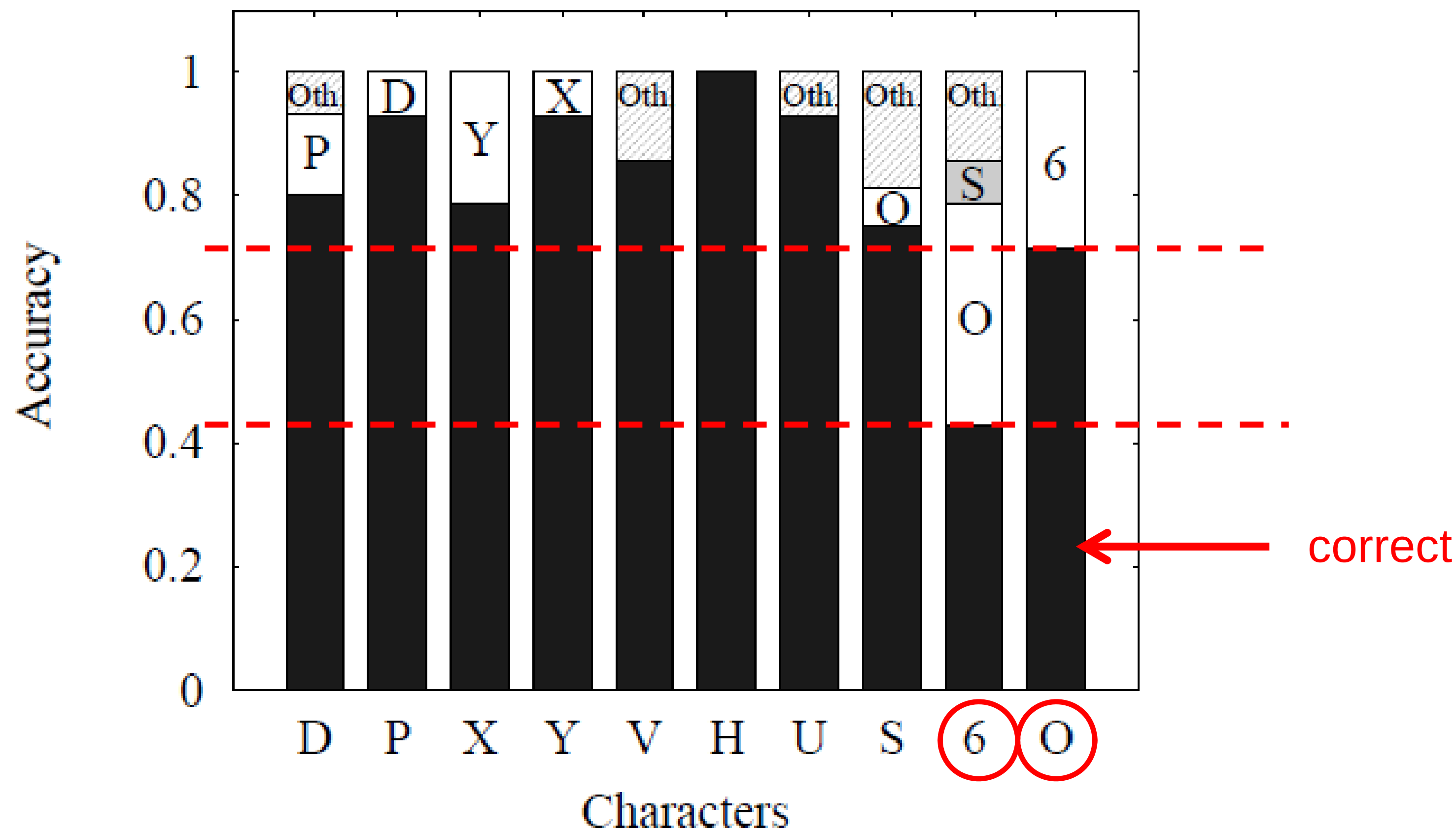
Average character recognition (stroke grammar)

- Trained writers: 91:9%
- Novice writers: 78:2%



Results:
Character disambiguation

Common set of strokes causes confusion



Results:
Median time to correctly write character

- 4.3 sec (all)
- 3.02 sec (min)

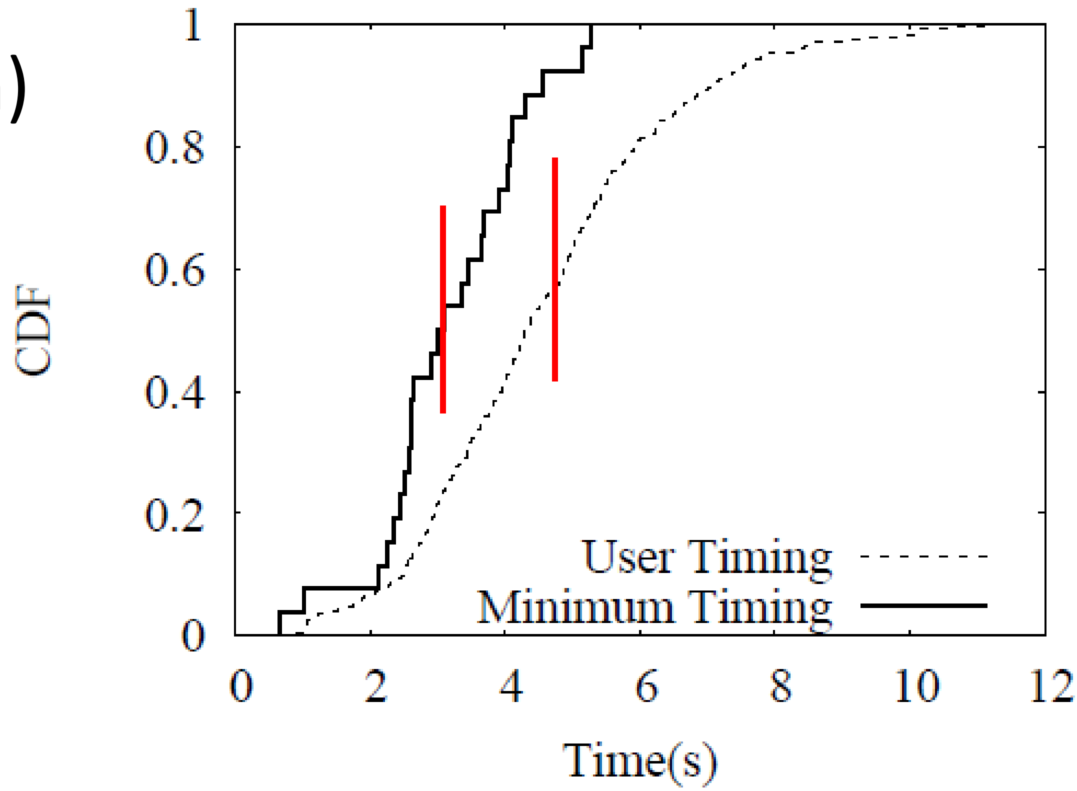


Figure 13: Distribution of time to correctly write English characters with P3.

Results:
Hospital Patients

- Only 5 patients
  - Cognitive disorders and motor impairments
  - Write 8 random letters
  - Not allowed to observe patients
  - Problem pressing button

Table 3: Patient performance.

Patient ID	1	2	3	4	5
Accuracy	1/8	1/8	1/8	5/8	could not press button

- Suggestions from doctors: Try left-hand to emulate speech-impaired patients.

Discussions/Conclusions/Future Work

- Not extensive, only 10 students, 5 patients
- Prototype, shows possibilities
- Improve prototype, new user-experience “that complements keyboards and touch-screens.”
- Integrate gyroscope in next PhonePoint Pen
- TEDxDuke - Vansh Muttreja on the Virtual White Board - A New Way of Remote Collaboration
  - http://www.youtube.com/watch?v=vmyXJzkfevY

Discussions/Conclusions/Future Work

- Some other ideas
- Use back camera to optically track movement?
- Write in the air
- Geo-location
- Augmented reality

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Questions?