MobileASL: Making Cell Phones Accessible to the Deaf Community

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American Sign Language (ASL)

- ASL is the preferred language for about 500,000 - 1,000,000 Deaf people in the U.S and most of Canada.
- ASL is not a code for English
- Signs usually occur within the “sign-box”
- Composed of location, orientation, shape of hands and arms + facial expressions
- Usually uses 2 hands, but one-handed signing not uncommon

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Current Technology for Deaf People (text)

TTY

Sidekicks and Blackberries
(text, pictures, non-real-time video)

Benefits:

Low bandwidth
Mobile (PDAs)

Problems:

English, not ASL

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Current Technology for Deaf People (video phones)

Set-top boxes

Web cams

Benefits:

ASL, not English

Problems:

Requires high bandwidth
Not mobile

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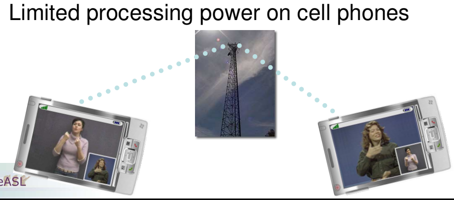
Our goal:

- ASL communication using video cell phones over current U.S. cell phone network

Challenges:

- Limited network bandwidth
- Limited processing power on cell phones



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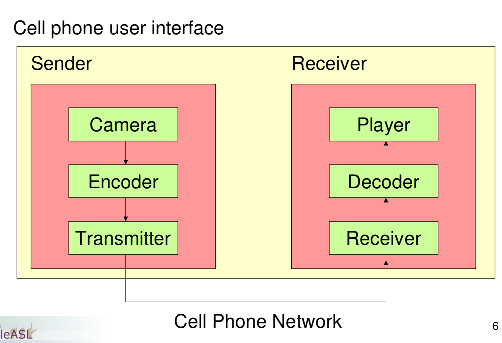
Architecture



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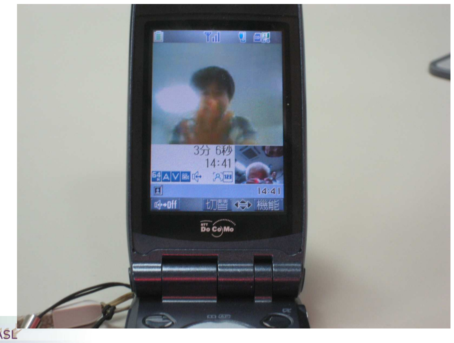
Cell Phone Network Constraints

- MobileASL is about fair access to the current network
  - As soon as possible, no special accommodations
- Low bit rate constraint
  - GPRS - Ranges from 30kbps to 80kbps (download)
- Low Power
  - Cell phones run at much lower Hz then PCs
- New mobile broadband services
  - Higher bandwidth for download, not upload.

What about 3G?



Portrait

- Special Codec from Microsoft Asia
- Low Bandwidth, Low Power, small size video (160 x 120)
- May not be suitable for sign language

Keman Yu, Jiangbo Lv, Jiang Li and Shipeng Li, 2003

Codec Used: x264*

- Open source implementation of H.264 standard
- Doubles compression ratio over MPEG2
- x264 offers faster encoding
- Main profile
- Off-the-shelf H.264 decoder can be used

*The code is written from scratch by Laurent Aimar, Loren Merritt, Eric Petis, Min Chen, Justin Clay, Mans Rullgard, Radek Czyz, Christian Heine, Alex Izvorski, and Alex Wright. It is released under the terms of the GPL license.

Outline

- Motivation
- Introduction
- User Studies
- Rate, distortion, complexity optimization
- X264 implementation
- User Interface
- Current and future research

MobileASL Focus Group

- 4 Deaf people, mid-20s to mid-40s,
- Open ended questions:
  - Physical Setup
    - Camera, distance, …
  - Features
    - Compatibility, text, …
  - Privacy Concerns
    - ASL is a visual language
  - Scenarios
    - Lighting, driving, relay services, …

Implications of Focus Group

- "I don't foresee any limitations. I would use the phone anywhere: the grocery store, the bus, the car, a restaurant, … anywhere!"
- There is a need within the Deaf Community for mobile ASL conversations
- Existing video phone technology (with minor modifications) would be usable

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Eyetracking Studies

- Participants watched ASL videos while eye movements were tracked
- Important regions of the video could be encoded differently

* Muir et al. (2005) and Agrafiotis et al. (2003)

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Eyetracking Results

- 95% of eye movements within 2 degrees visual angle of the signer's face (**demo**)
- Implications: Face region of video is most visually important
  - Detailed grammar in face requires foveal vision
  - Hands and arms can be viewed in peripheral vision

* Muir et al. (2005) and Agrafiotis et al. (2003)

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Mobile Video Phone Study

- 3 Region-of-Interest (ROI) values
- 2 Frame rates, frames per second (FPS)
- 3 different Bit rates
  - 15 kbps, 20 kbps, 25 kbps
- 18 participants (7 women)
  - 10 Deaf, 5 hearing, 3 CODA*
  - All fluent in ASL

* CODA = (Hearing) Child of a Deaf Adult

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Example of ROI

Varied quality in fixed-sized region around the face

0 ROI | 6 ROI, 2x quality in face | 12 ROI, 4x quality in face

- (demo)

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Examples of FPS

- Varied frame rate: 10 fps and 15 fps
- For a given bit rate:
  Fewer frames = more bits per frame

- (demo)

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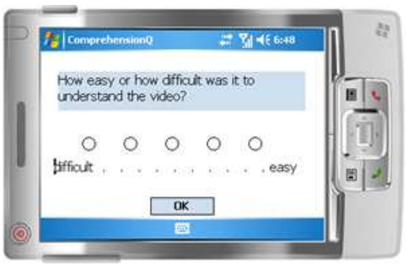
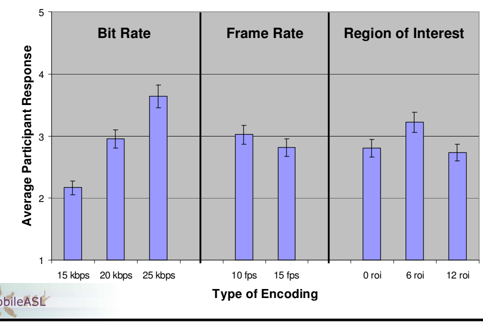
Questionnaire



User Preferences Results



Implications of results

- A mid-range ROI was preferred
  - Optimal tradeoff between clarity in face and distortion in rest of “sign-box”
- Lower frame rate preferred
  - Optimal tradeoff between clarity of frames and number of frames per second
- Results independent of bit rate

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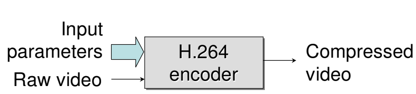
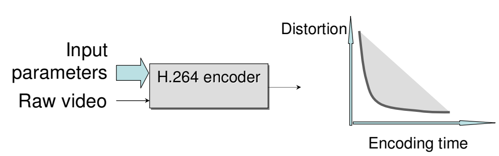
Rate, distortion and complexity optimization



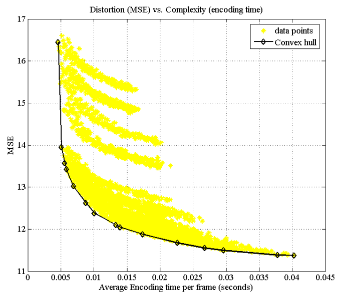
- Objective: Achieve best possible quality for least encoding time at a given bitrate

Parameter Settings



input parameters	**# of options**
# of reference frames	16
motion estimation	7
partition size	10
quantization method	3
Total = 16x7x10x3 =	**3360** tests/video clip

Time – Complexity Tradeoff



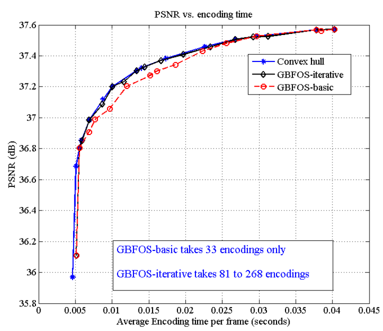
30 kbps
10 ASL videos

GBFOS Approach

Chou, Lookabaugh, Gray, 1989

- Choose input parameter that minimizes the slope on the convex hull and repeat.
- Parameter settings are not independent.
- Basic – Compute slopes once.
- Iterative – Recompute slopes after each parameter is chosen.

PSNR vs. Average Encoding Time



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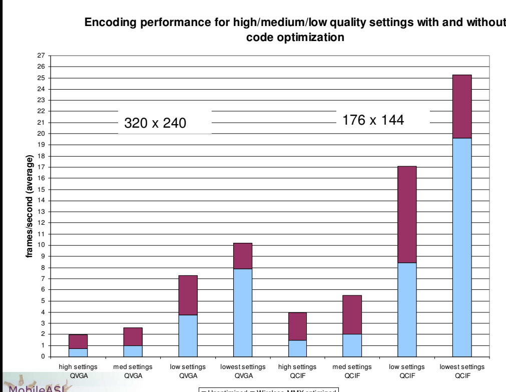
Encoding/Decoding on the Cell Phone

- Implemented a command-line version of x264 on a cell phone using Windows Mobile Edition 5.0.
- Required significant modifications to the Linux based x264 codec.



Examples of Low Frame Rates

- Demo

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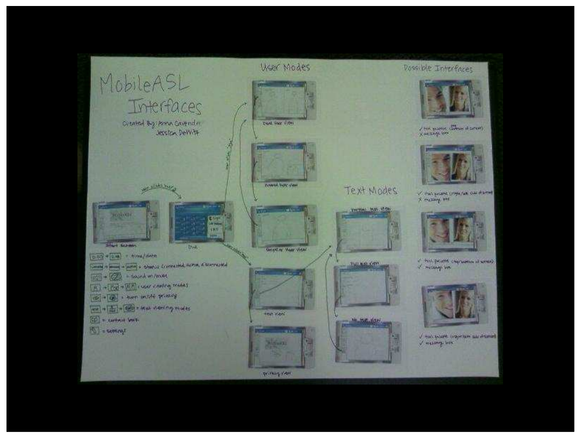
User Interface Design: Goals

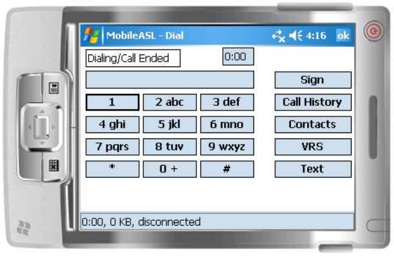
- Usable, intuitive, easy to learn
- Inspired by Deaf users
- Utilize existing knowledge (VP, Webcam, Sorenson …)
- Design stages:
  - Story boards
  - Paper prototype testing
  - Digital prototyping



Basic Interface

Split Screen with Text

Call Set-up



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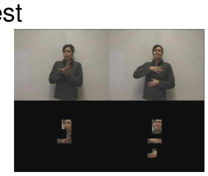
Current Work

- Dynamic Region-of-Interest
  - Skin detection algorithms
- Objective Metrics
  - For ASL Understandability
- Activity Recognition
  - Fingerspelling, signing, "listening"
- Building the System
  - Transmission, Receiving, Playing
  - Packet loss on GPRS



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Dynamic Region of Interest

- Use skin detection algorithms to drive region of interest.
- Fast skin detection algorithms exist
- Demo

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Objective Metric

- Importance
  - Face
  - Hands
  - Signing Box
- Weighted MSE based on where the pixels are

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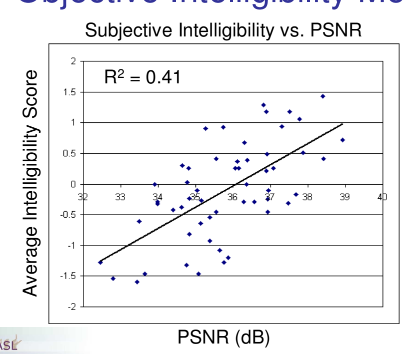
Objective Intelligibility Metric



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Objective Intelligibility Metric

$$I = 10\log_{10}\frac{255^2}{F \times MSE_F + H \times MSE_H}$$

where $F = 0.6$ and $H = 0.4$

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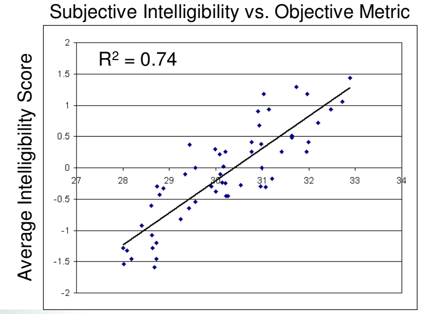
Objective Intelligibility Metric

Subjective Intelligibility vs. Objective Metric



Objective Intelligibility

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Activity Recognition

- Motivation:
  - Finger spelling requires a higher bit rate and/or frame rate for intelligibility than signing
  - We want to minimize encoding complexity when not signing.
- Goal:
  - Recognize these three states: finger spelling, signing, not signing
  - Perform recognition in real time

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Possible Solution

- Use H.264 motion vectors as features
- Use probabilistic techniques to automatically recognize activity
  - Hidden Markov Models
  - Kalman filters or particle filters

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Building the System

- in C#:
  - Really easy to develop GUIs.
  - Developers can only use their predefined interface for the camera. The interface is simple, but extremely limited.
- In C++:
  - GUI development much more complex.
  - Accessing camera requires knowledge of windows COM system.

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Thanks

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