IEEE **EMB**

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"Engineering Innovation in Global Health"

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UT DALLAS | Erik Jonsson School of Engineering & Computer Science

EMBC 2012

Design and Evaluation of the PDA-Based Research Platform for Electric and Acoustic Stimulation

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FEARLESS engineering

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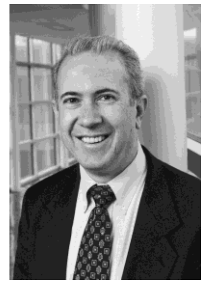
Obituary: Philip C Loizou

A pioneer in speech processing and cochlear implant research, Prof. Philip Loizou passed away at age 46 on July 22, 2012

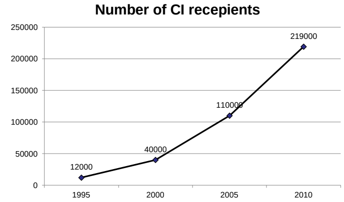


Philip Loizou was an internationally known leader in signal and speech processing, speech perception and cochlear implant research. He formulated advancements in both signal processing and cochlear implant devices for electrical stimulation of the inner ear of profoundly deaf people that send sound signals to the brain. His algorithms also helped improve the performance of cochlear implants by programming the device to operate more effectively in diverse listening environments.

Philipos C. Loizou received the B.S., M.S., and Ph.D. degrees from Arizona State University (ASU), Tempe, AZ, in 1989, 1991, and 1995, respectively, all in electrical engineering. From 1995 to 1996, he was a Postdoctoral Fellow in the Department of Speech and Hearing Science, ASU, where he was involved in research related to cochlear implants. From 1996 to 1999, he was an Assistant Professor at the University of Arkansas at Little Rock, Little Rock, AR. He later moved to join the Department of Electrical Engineering, University of Texas at Dallas, Richardson, TX, where he helped co-found the Center for Robust Speech Systems (CRSS) in the Jonsson School and directed the Speech Processing and Cochlear Implant Labs within CRSS. He served as Professor and held the Cecil and Ida Green Chair in Systems Biology Science at UT Dallas.

Cochlear Implant usage today

- a benchmark technology in neural prosthesis
  - high success rate in restoring hearing to the deaf
  - growing and widespread use
  - More than 219,000 people with implants as of Dec. 2010 (FDA)

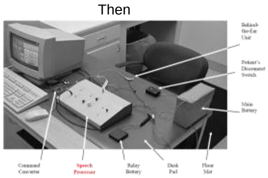


Challenges and current research

- Challenges
  - Environmental noise
  - Performance in multi-talker environment
  - Music and melodies
  - Limited spectral resolution
  - Limited pitch information
- On-going Research
  - CI growth is driven by extensive research both in academia and industry in
    - developing better sound processing algorithms for sound representation, and
    - novel design of stimulators and electrode arrays for improved stimulation patterns
  - research is largely dependent upon having access to a research platform which could be used to design new experiments and evaluate user performance over time.

Existing Research platforms

Then



Now

Research processor	Advantages	Disadvantages
SPEAR3 (Nucleus) 	• Portable • Allows for real-time processing • Suitable for bilateral experiments	• Not easy to program (requires assembly language programming) • Not flexible in implementing complex algorithms • Does not allow for offline implementation of complex algorithms
CRI (Clarion)	• Allows for real-time processing • Allows for offline implementation of complex algorithms • Can be programmed in C	• Not portable • Not suitable for bilateral studies
RIB (Med-El)	• Allows for offline implementation of complex algorithms • can be programmed in MATLAB	• not portable • not suitable for real-time processing • not suitable for bilateral studies

Limitations
- **Flexibility-** to allow for quick development and evaluation of new research ideas
- **Portability** - to allow for realistic assessment of new algorithms after long-term evaluation
- **Ease of use** – accessible to all researchers interested in clinical and animal studies
- **Wearability**,
- **Easy of programmability**,
- **Long-term evaluation** and
- **Limited features** to design intricate experiments.

PDA-based Platform

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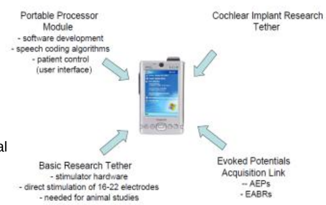
UTD A smartphone/PDA–based research interface

Features:

- Bilateral Cochlear Implants
- Bimodal Capability (Combined Electric and Acoustic Stimulation)
- Two Modes of Operation
  - Real-time mode
  - Offline mode
- Portable Stimulator for animal studies
- Recording Unit for collecting EEG or cortical auditory evoked potentials (CAEPs)



Concept of an App for the implant!

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HARDWARE OVERVIEW

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UTD PDA/Smartphone

- A portable processor in the form a of a smart-phone or a PDA for implementing and evaluating novel speech processing algorithms after long-term use
- Windows enabled PDA allows programming in C/C++/C# and also in LabVIEW

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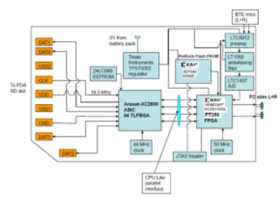
UTD Interface Board

- Plugs into the (Serial Digital IN/OUT) SDIO port of the PDA
- Interface card to communicate with the implant
- Implements communication protocols



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UTD BTE + Coil

- Modified HS8 BTE houses a microphone
- Two BTEs+ Freedom coils (from Cochlear Ltd.) connect with SDIO board using a custom cable

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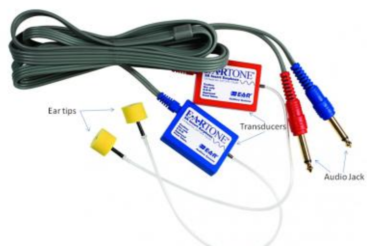
UTD Additional Hardware – Insert phones for acoustic stimulation



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SOFTWARE OVERVIEW

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Modes of Operation

Real-time Sound Processor which allows both electric only and electric plus acoustic stimulation (EAS) in real-time

Offline Sound Processor which allows speech processing in offline mode through MATLAB running on a PC. It also supports bimodal stimulation as well as allows researchers to conduct psychophysical experiments.

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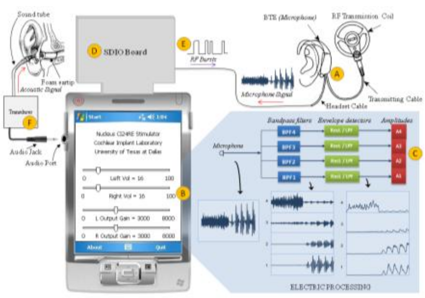
Real-time mode

The acoustic signal is picked up by the microphone (A), sent (via the headset cable) to the SDIO interface board (D), which is then sampled and transmitted to the PDA.

The PDA (B) processes the signal and generates a set (one for each channel of stimulation) of amplitudes (C).

These amplitudes are sent to the SDIO interface board (D), which are then coded for transmission to the cochlear implant in the form of RF bursts (E).

At the same time, the processed audio buffer is sent to the tranducer (F) which presents the acoustic signal to the contralateral ear via the insert eartips.



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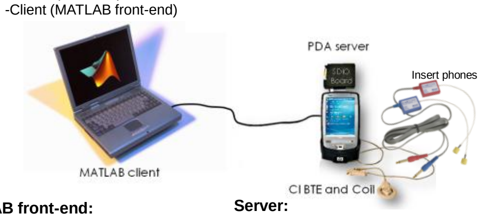
Offline Speech Processor

Two main components of Offline Mode
-Server (PDA end)
-Client (MATLAB front-end)



MATLAB front-end:

- Prepare stimuli data
- Specify parameters
- Ensure safe parameters
- Arrange data in a specific protocol
- Call socclient dll

Server:

-Receive data from the client
-Perform Error Checking
- Forward electric stimuli to the SDIO board and acoustic stimuli to the insert phones

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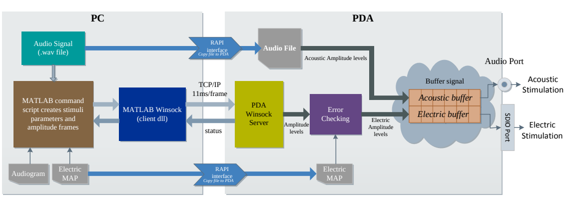
Offline Mode



- MATLAB is used as front-end layer to the software.
- The stimuli are first created in MATLAB, then a dll (socclient) is called to establish the connection with the PDA and stream the stimuli to the implant.
- Stimuli comprise of envelope amplitudes and stimulation parameters (e.g., active electrodes, rate, pulse width, etc).

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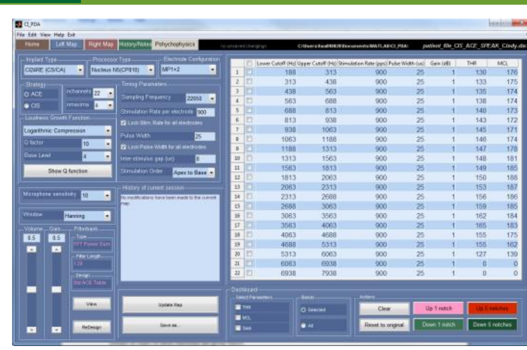
MATLAB Front End



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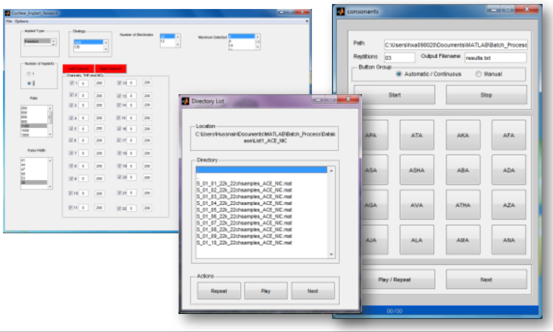
Applications



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EVALUATION WITH CI SUBJECTS

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Evaluation Tasks

- Speech Intelligibility
  - In quite
  - 10dB SNR noise
  - 5dB SNR noise
- 5 bimodal subjects were tested
- Both real-time and offline processors were used
- Scores from the clinical processor were used as a benchmark criterion for fair comparison

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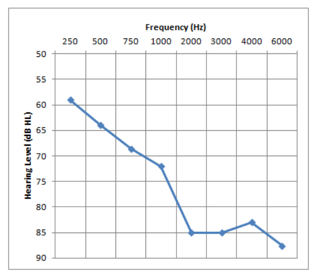
Average Hearing loss in acoustic ear



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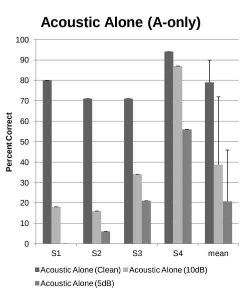
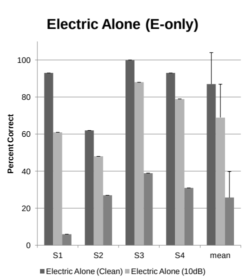
E-only and A-only results





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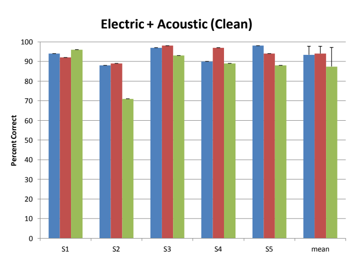
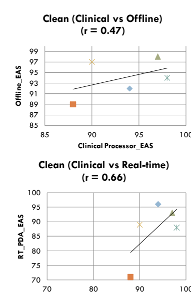
E+A (Quiet)





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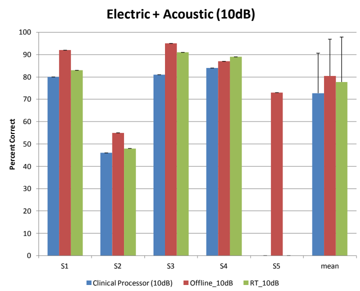
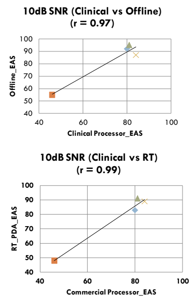
UTD E+A 10dB SNR





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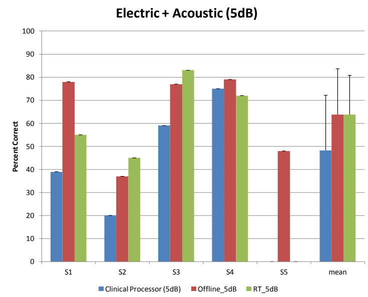
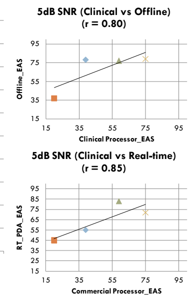
UTD E+A 5dB SNR





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UTD EAS results

- EAS shows an improvement in scores as compared to A-only and E-only scores.
- Effect is more pronounced in noisy conditions.
  - For example, percentage correct scores drastically improved from 21 percent with A-only to 60 percent with EAS. This is even greater than the sum of A and E alone.
- There is a strong correlation between all three processor types in all conditions.
- The Pearson's correlation coefficients for RT and clinical processor at 10dB and 5dB SNR were 0.99 and 0.85 respectively. For the offline processor in the same SNR, correlation coefficients were 0.97 and 0.80 respectively.
- These strong correlations suggest that the PDA platform delivers comparable performance with the commercial clinical processor.

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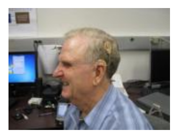
UTD Remarks on Evaluation

- It should be pointed out that the results reported here are from acute studies.
- Given the differences in microphones used in the BTE and those used in the commercially available speech processors, differences in hardware, as well as differences in the implementation of the ACE coding strategy, it is reasonable to expect that the users would need to acclimate to the use of PDA processor.



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UTD Conclusion

- Hardware and Software Architecture of the PDA platform
- Flexibility in programming and feature space provided by the platform
- Capability for diverse experiments with the platform
- Electric plus acoustic stimulation
- Psychophysics
- Evaluation with human subjects and results
- strong correlations of results against the clinical processor suggest that the PDA platform delivers comparable performance with the commercial clinical processor

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UTD Future Plans – Take home trials

- Our next step is to undertake long-term clinical evaluation of the platform with take-home trials.
- Portability and wearability of the PDA platform makes it possible for the users to wear the platform on a daily basis until they fully adapt to the new processor.
- The possibility of conducting chronic studies with the PDA processor allows researchers to carry out long-term evaluation of novel coding algorithms and conduct experiments that would otherwise not be possible.
- This in turn will open new possibilities in cochlear implant research and development.

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Q & A

Thank you

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