Department of Electronic & Electrical Engineering
Faculty of Engineering Sciences

UCL

A multiplexed star electrode array for session-independent silent speech recognition

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Silent speech recognition

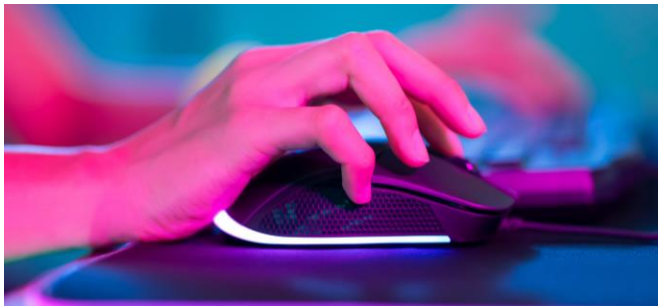
Speech recognition without the use of audio signals, through other correlated bio-signals. Allows for detection of silent/mouthed speech.

Is as intuitive and fast as speech but is also:

- Private and convenient in public.
- Unaffected by environmental noise
- Accessible to people with difficulty vocalizing

High impact applications such as:

Defense ~ 500B USD market by 2030



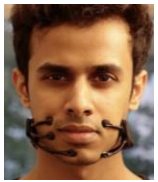
Human-AI interaction ~ 100B USD market by 2030

EMG-based silent speech recognition

Electromyography (EMG) signals from facial muscles is a common modality for silent speech recognition.

Typical Architecture:

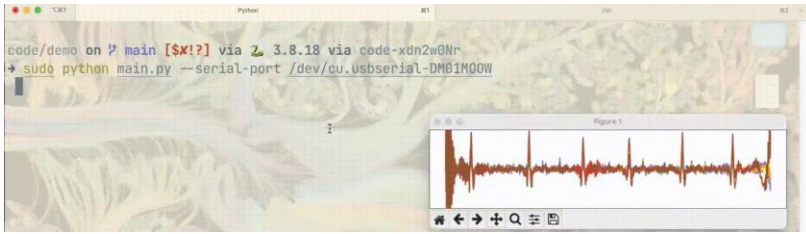
Electrodes → Signal Acquisition → Digital Filters → Word Classifier

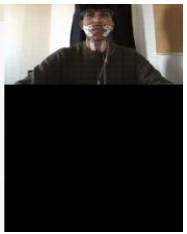


State of the art

AlterEgo (2019), 91% accuracy over a 30-word vocabulary

Replicated state-of-the-art with a custom electrode brace





System performance **requires precise electrode positions**, accuracy reduces to 40% after electrode shift.

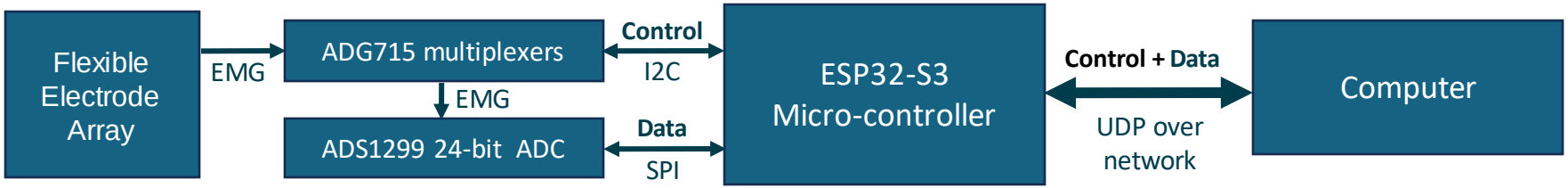
Research Question:

Investigating the impact of electrode alignment with facial muscles to maximise signal-to-noise ratio (SNR) in silent speech interfaces.

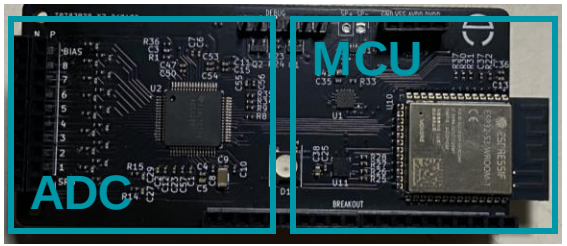
Design and Development

Develop an 8-channel electrode array capable of actively switching the orientation of its electrodes.

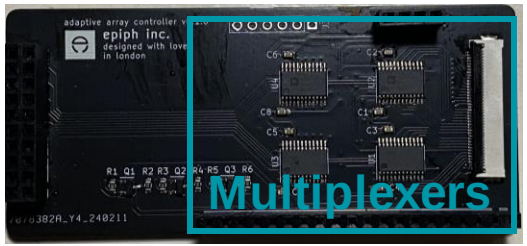
System Design



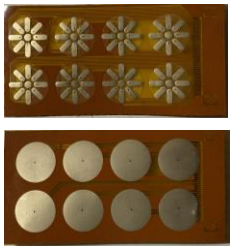
System Development



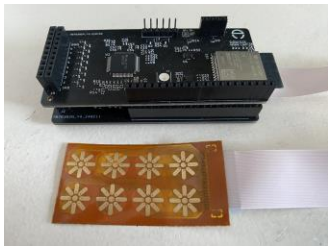
Main Control Board



Multiplexer Board



Flexible Electrodes
(top) multiplexed, (bottom) control



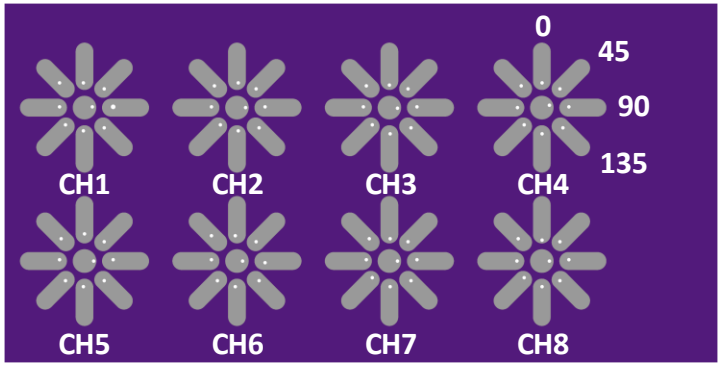
Full Setup

Experimental Procedure and Development

Identify electrode directions which maximize SNR, and investigate variability in directions due to electrode shift.

Methodology

1. Record one minute of noise in a relaxed state.
2. Record a phonetically balanced passage that ensures a variety of speech muscle activations are sampled.
3. Calculate SNR using mean-squared value of noise and recorded signal.
4. Repeat for each electrode direction (0, 45, 90, 135) + all directions + no directions selected + control array.
5. Repeat across 2 sessions to sample variability in the presence of electrode shift.



Detailed view of electrode array:
showing electrode directions and channels

User wearing electrodes:
Arrows indicate orientation compared to figure above.

Electrodes adhered with bio-safe double-sided tape.

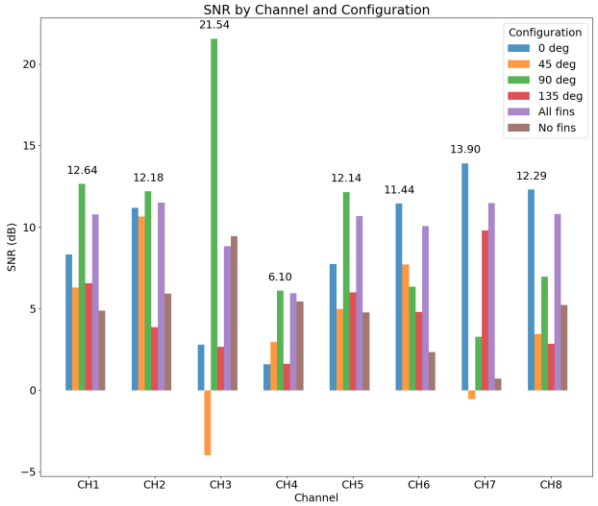
Key Results

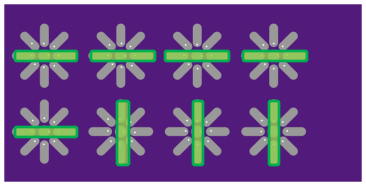
Optimally oriented electrodes **consistently outperform** average control electrode SNR of 10 dB.

The optimal orientation of the electrode **changes significantly** between sessions.

Multiplexing can offer significant SNR improvements.

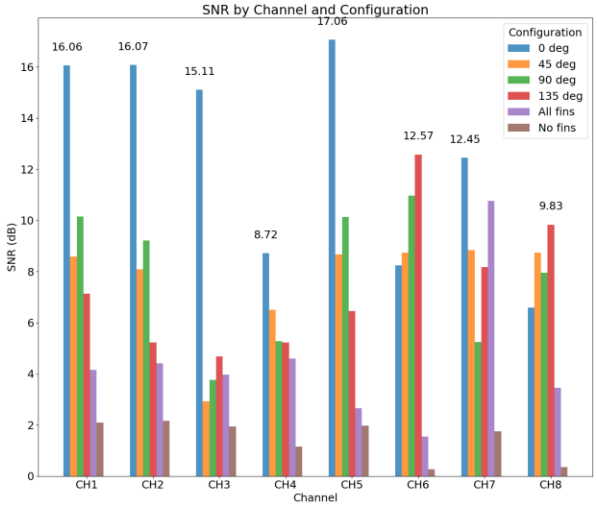
Session 1

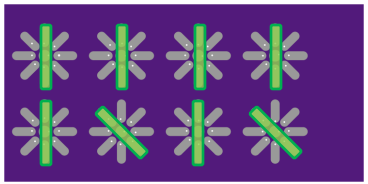




Optimal configuration for Session 1

Session 2





Optimal configuration for Session 2

Conclusion

1. A novel approach to optimizing SNR for silent speech recognition through electrode alignment is investigated.
2. A multiplexing system enabling configurable electrode orientation is developed.
3. Results show evidence that dynamic electrode alignment has the potential to boost SNR significantly compared to a static electrode array.
4. System can be improved with automatic electrode alignment for user-administrable silent speech interfaces that are robust to electrode placement.