Voice Research for Healthcare Application

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Research

Mobile Computing and Privacy (MobCP) Research Lab, 2015 - Now

PI: Xiaohui Liang

Students:

Tran   Zhu   Obyat   Thamer   Hadian

Research Interests: Mobile Healthcare, Internet of Things, Wearable Computing, and Security and Privacy for Communication Systems
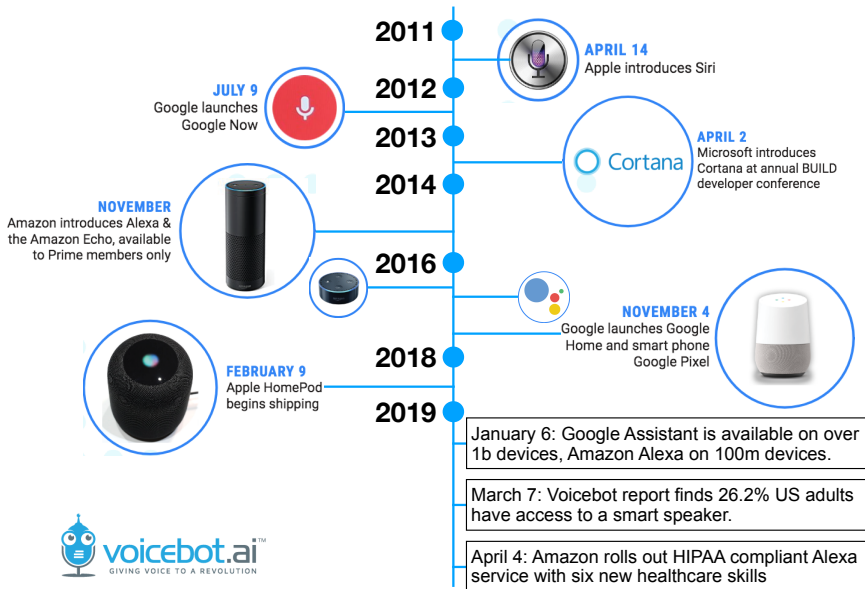
Current Research Projects

Novel Healthcare Applications

- Voice-based Cognitive Assessment in Older Adults (NIH/NIA R01 2019-2013)

- Wearable-based Physical Function Assessment in Smart Clinics
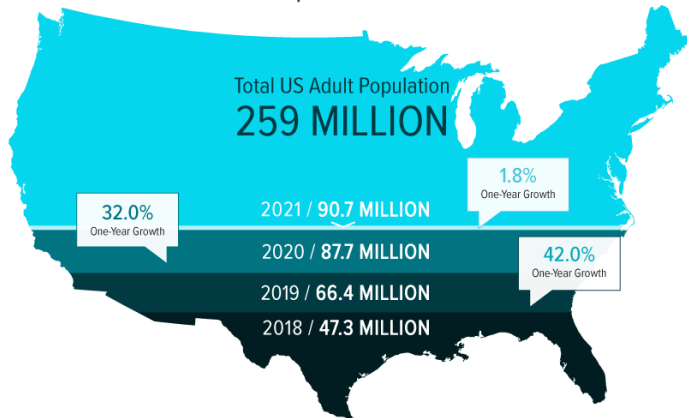
Security & Privacy

- Voice Assistant Systems

Voice Assistant Systems

2011

2012

2013

2014

2016

2018

2019

APRIL 14
Apple introduces Siri

JULY 9
Google launches
Google Now

APRIL 2
Microsoft introduces
Cortana at annual BUILD
developer conference

Cortana

NOVEMBER
Amazon introduces Alexa &
the Amazon Echo, available
to Prime members only

NOVEMBER 4
Google launches Google
Home and smart phone
Google Pixel

FEBRUARY 9
Apple HomePod
begins shipping

January 6: Google Assistant is available on over
1b devices, Amazon Alexa on 100m devices.

March 7: Voicebot report finds 26.2% US adults
have access to a smart speaker.

April 4: Amazon rolls out HIPAA compliant Alexa
service with six new healthcare skills

voicebot.ai™
GIVING VOICE TO A REVOLUTION

Voice Assistant Systems

U.S. Adult Smart Speaker Installed Base 2021

Total US Adult Population
259 MILLION

1.8%
One-Year Growth

32.0%
One-Year Growth

2021 / 90.7 MILLION

2020 / 87.7 MILLION

42.0%
One-Year Growth

2019 / 66.4 MILLION

2018 / 47.3 MILLION

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Cognitive Assessment in Older Adults

Problem: Early detection of the cognitive decline involved in Alzheimer's Disease and Related Dementias (ADRD) in older adults living alone is essential for developing, planning, and initiating interventions and support systems to improve patients' everyday function and quality of life.

Clinic	Conventional early	Voice Assistant	Home
Effort	diagnosis methods	Systems (VAS)	Passive
Expensive	Impractical	Practical	Low-cost
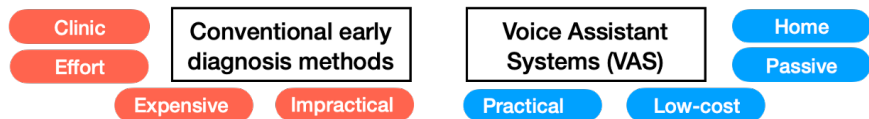
Intellectual merit: Develop a low-cost, passive, and practical home-based assessment method using Voice Assistant Systems (VAS) for early detection of cognitive decline, including a set of novel data mining techniques for sparse time-series speech.

Broader impacts: If successful, the proposed system may be widely disseminated for the early diagnosis of cognitive impairment to complement existing diagnostic modalities that could ultimately enable long-term patient and caregiver planning to maintain individual's independence at home.

# Our Research Approach

Methodology
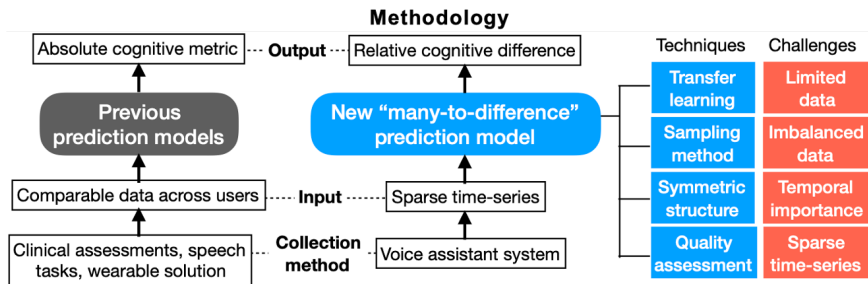
- Xiaohui Liang, PI, Assistant Professor of Computer Science at UMass Boston
- John Batsis, MD, Geriatrician, Co-I, Associate Professor at the University of North Carolina at Chapel Hill
- Robert Roth, Neuropsychologist, Co-I, Associate Professor at the Geisel School of Medicine at Dartmouth
- David Kotz, Consultant, Professor of Computer Science at Dartmouth
- Brian MacWhinney, Consultant, Professor of Psychology and and Modern Languages at Carnegie Mellon University

Our Research Approach

- <u>Passiveness.</u> VAS conversations are initiated by users.
- <u>Long-term behavior.</u> VAS data may be generated at a regular time and with a regular pattern.
- <u>No external factors.</u> VAS data is collected from a user in a private environment.
- <u>Wide adoptability.</u> VAS data can be collected from a wide range of devices (smartphone, smart speaker, computer) and applications.
- <u>Privacy.</u> Consent on VAS data collection and analysis when purchasing the device.

Our Research Approach

Our team will conduct long-term evaluations with selected participants.
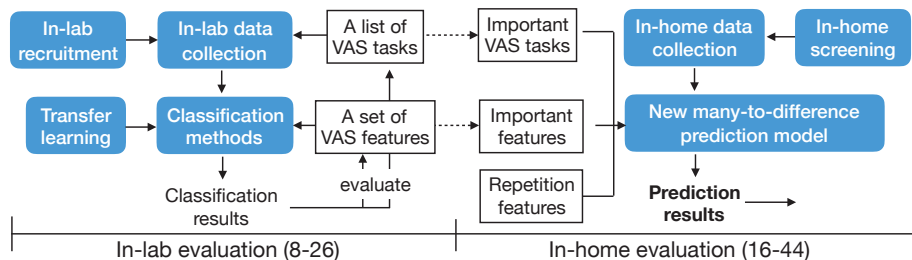
Consent + Baseline Data Collection Protocols (1.5 hour)

RA and participant finish the consent process and assessments

1. Consent Form
2. Consent Form Comprehension Interview
3. OARS: Older Americans Resources and Services questionnaire is a means of determining the impact of services and alternative service programs on the functional status of older adults
4. GAI: Geriatric Anxiety Inventory
5. GDS: Geriatric Depression Scale
6. MoCA: Montreal Cognitive Assessment
7. Home Environment Interview is used to assess the environment of the participants' homes, such as the size and type of home, the number of residences, and daily home activities.

Our Research Results

All research updates can be found at CogVox.org.

1. "Exploring Deep Transfer Learning Techniques for Alzheimer's Dementia Detection," Frontiers in Computer Science Special Issue on Alzheimer's Dementia Recognition through Spontaneous Speech, Accepted on Marc 11, 2021.

2. "Evaluating Voice-Assistant Commands for Dementia Detection," minor revision, Elsevier Computer Speech and Language Special Issue on Speech Based Evaluation of Neurological Diseases, 2021.

3. "WavBERT: Exploiting Semantic and Non-semantic Speech using Wav2vec and BERT for Dementia Detection," submitted to INTERSPEECH 2021.

4. "Privacy Concerns Among Older Adults using Voice Assistant Systems," submitted to the Gerontological Society of America (GSA) annual conference, 2021.

5. "Exploiting Fully Convolutional Network and Visualization Techniques on Spontaneous Speech for Dementia Detection," arXiv preprint arXiv:2008.07052 (2020).
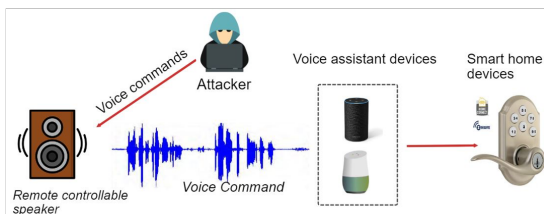
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Voice Security Problem

VAS is subject to new security attacks because

- Voice transmission has the broadcast nature.
- Voice is easy to forge, and voice is the only input to the system.

Our Research Results

1. WiVo: Enhancing the Security of Voice Control System via Wireless Signal in IoT Environment, International Symposium on Theory, Algorithmic Foundations, and Protocol Design for Mobile Networks and Mobile Computing (MobiHoc) 2018.

2. Exploiting Physical Presence Sensing to Secure Voice Assistant Systems, IEEE International Conference on Communications (ICC), 2021.

Voice Privacy Problem

VAS raises new privacy concerns because

- Voice queries are linked to users' accounts, resulting in long-term and continuous profiling at the service provider.

- User login behavior enables the Voice Service Provider (VSP) to link the voice queries to the same user regardless of the device-level and network-level anonymization techniques.

- Conventional network-level anonymizers, such as TOR and VPN, used for preventing traffic analysis attacks, do not effectively anonymize the source of user's voice data from the VSP.

Our Research Results

1. Privacy-preserving Voice-based Search over mHealth Data. Smart Health Journal, vol. 12, pp. 24-34, 2019.

2. Exploiting Privacy-preserving Voice Query in Healthcare-based Voice Assistant System. IEEE International Conference on Communications (ICC), 2020

3. Exploiting Peer-to-peer Communications for Query Privacy Preservation in Voice Assistant Systems. Peer-to-Peer Networking and Applications, Springer, 2020.
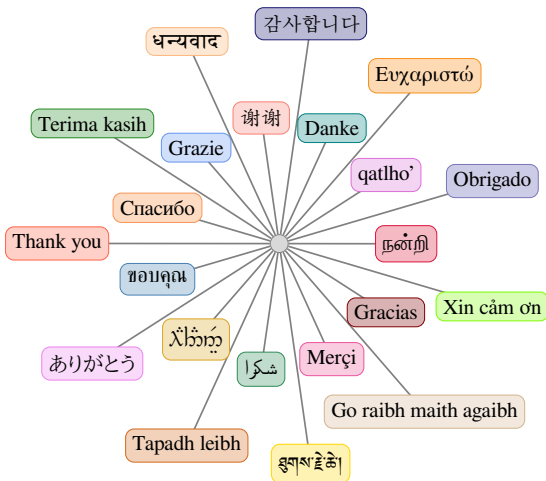
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