A Survey on Mouth Modeling and Analysis for Sign Language Recognition

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Outline

- Is mouth linguistically significant for Sign Language?
- Review of existing methods of mouth modeling for Automatic Sign Language Recognition.
- Future work, challenges and potentials.

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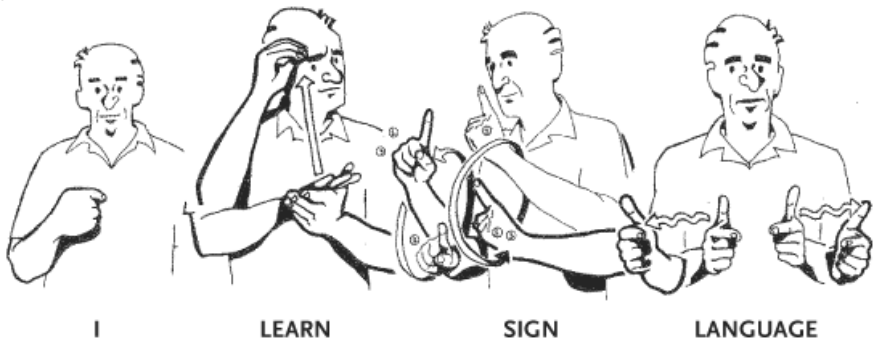
Sign Language (SL)

- About 5% of the worldwide population suffers from hearing loss to some degree.
- 1% of the worldwide population use SLs as their native languages (~70 million deaf people).
- SLs are also used from people who cannot physically speak (mutism).
- There is not a unique international SL. Each country has its own, so there are hundreds of different SLs.



Automatic SL Recognition

- Deaf people encounter many difficulties in the every day life (education, work, use of the internet, etc.):
  - Limited reading/writing skills in the spoken language (for them it is a foreign language with fundamentally different grammatical structure).
  - The vast majority of the rest of the population is unable to use SL.
- *Automatic SL Recognition (ASLR)* can greatly support the Deaf community.
- However, it is still far from being mature technology, especially compared to text-based interaction or speech recognition.

SL Structure

- SLs are as rich and grammatically complex as spoken languages.
- Manual articulators
  - Phonemes (basic semantic SL components)
  - Hands shape, posture, location and motion
- Non-manual articulators
  - Prosody, lexical distinction, grammatical structure, adjectival/adverbial content
  - Head and body pose, facial expressions (through eyes, eyebrows, cheeks, lips), mouth movements
- Mouth is one of the most involved parts of the face in non-manuals.

Mouth Actions

- Mouth lexical articulators are separated in:

1) Mouth gestures:
   - Non-verbal components
   - Shape deformation, tongue movement, teeth visibility

2) Mouthings:
   - Silent articulators that correspond to a pronounced word or part of it.
   - Visual syllables (in most SLs only the first syllable of a word is articulated).

Mouth Actions

- Some argue that mouth actions (especially mouthings) are not linguistically significant.
  - W. Sandler, D. Lillo-Martin. “Sign language and linguistic universals”, Cambridge University Press, 2006.
  - A. Hohenberger, D. Happ. “The linguistic primacy of signs and mouth gestures over mouthing: Evidence from language production in german sign language”, The hands are the head of the mouth: the mouth as articulator in sign language”, p. 153-189, Signum, 2001.
- Recent research has shown that they contribute significantly to the semantic analysis of SLs.
  - S. Liddell. “Grammar, gesture, and meaning in American Sign Language”. Cambridge University Press, 2003.
  - M. Nadolske, R. Rosenstock. “Occurrence of mouthings in american sign language: a preliminary study”, Trends in linguistics studies and monographs, 2007.
  - P. Boyes-Braem, R. Sutton-Spence. “The hands are the head of the mouth”, Signum-Verlag, 2001.

Mouth Actions

- The frequency of mouth actions is different for each SL.
- It depends on both the context and the grammatical category of the manual sign they occur with.
- Most mouth actions have a *prosodic* interpretation while others have *lexical* meaning.
- In some cases, the mouth articulates physical events, emotions or sensations (types of sounds, noise, disturbances, heaviness, types of textures etc.).

Mouth Actions Examples

- “late” in American SL: no mouth action

- “not yet” in American SL: the tongue touches the lower lip

Source: ASL University (http://www.lifeprint.com/)

Mouth Actions Examples

- “brother” in German SL: mouth frown

- “sister” in German SL: mouth stretch

Source: U. von Agris, M. Knorr, and K. F. Kraiss. “The significance of facial features for automatic sign language recognition”, FG, 2008.

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Mouth Modeling in ASLR

- ***[1] Parashar:*** *A.S. Parashar. "Representation and interpretation of manual and non-manual information for automated american sign language recognition", PhD thesis, Univ. of South Florida, 2003.*
- ***[2] v. Agris et al.:*** *U. von Agris, M. Knorr, K. F. Kraiss. "The significance of facial features for automatic sign language recognition", FG, 2008.*
- ***[3] v. Agris et al.:*** *U. Von Agris, J. Zieren, U. Canzler, B. Bauer, K.F. Kraiss. "Recent developments in visual sign language recognition", Universal Access in the Information Society, 2008.*
- ***[4] Nguyen et al.:*** *T.D. Nguyen, S. Ranganath. "Facial expressions in american sign language: tracking and recognition", Pattern Recognition, 2011.*
- ***[5] Schmidt et al.:*** *C. Schmidt, O. Koller, H. Ney, T. Hoyoux, J. Piater. "Enhancing gloss-based corpora with facial features using active appearance models", ISSLTAT, 2013.*
- ***[6] Schmidt et al.:*** *C. Schmidt, O. Koller, H. Ney, T. Hoyoux, J. Piater. "Using viseme recognition to improve a sign language translation system", IWSLT, 2013.*
- ***[7] Pfister et al.:*** *T. Pfister, J. Charles, A. Zisserman. "Large-scale learning of sign language by watching tv (using co-occurrences)", BMVC, 2013.*
- ***[8] Koller et al.:*** *O. Koller, H. Ney, R. Bowden. "Read my lips: Continuous signer independent weakly supervised viseme recognition", ECCV, 2014.*
- ***[9] Koller et al.:*** *O. Koller, H. Ney, R. Bowden. "Weakly supervised automatic transcription of mouthings for gloss-based sign language corpora", LREC, 2014.*
- ***[10] Benitez-Quiroz et al.:*** *C.F. Benitez-Quiroz, K. Gokgoz, R.B. Wilbur, A.M. Martinez. "Discriminant features and temporal structure of nonmanuals in american sign language", PloS one, 2014.*
- ***[11] Antonakos et al.:*** *E. Antonakos, V. Pitsikalis, P. Maragos. "Classification of extreme facial events in sign language videos", EURASIP Image and Video Processing, 2014.*
- ***[12] Antonakos et al.:*** *E. Antonakos, V. Pitsikalis, I. Rodomagoulakis, P. Maragos. "Unsupervised classification of extreme facial events using active appearance models tracking for sign language videos", ICIP, 2012.*

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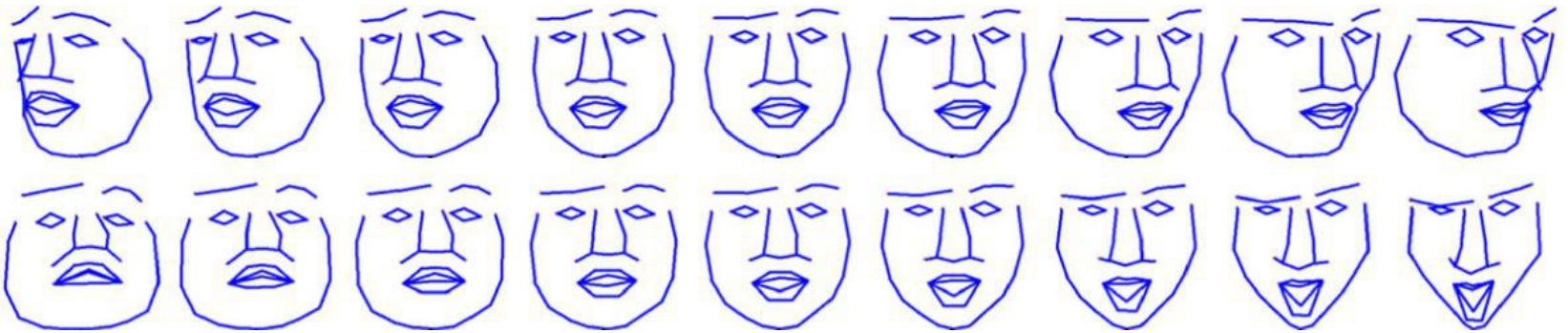
Mouth Modeling in ASLR

- There is limited work on mouth modeling for the task of ASLR.
- We categorize the existing works with respect to:
  - Mouth modeling and tracking method
  - Mouth features
  - Recognition/Classification technique
  - Linguistic phenomena
  - SL

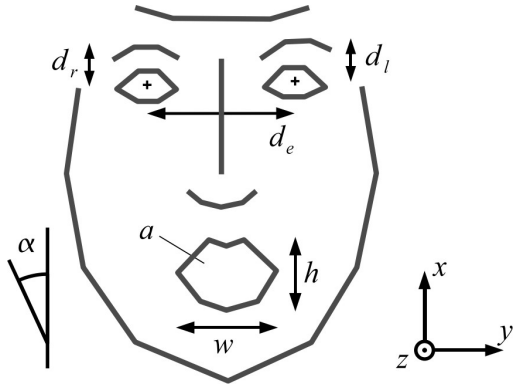
Mouth Modeling in ASLR

- Mouth modeling and tracking categorization:
  - Elliptical structure: *[1] Parashar*
  - Active Appearance Model: *[2,3] v. Agris et al.*
    [5,6] Schmidt et al.
    [8,9] Koller et al.
    [11,12] Antonakos et al.
  - Kanade-Lucas-Tomasi: *[4] Nguyen et al.*
    [7] Pfister et al.
  - Manual Annotations: *[10] Benitez-Quiroz et al.*

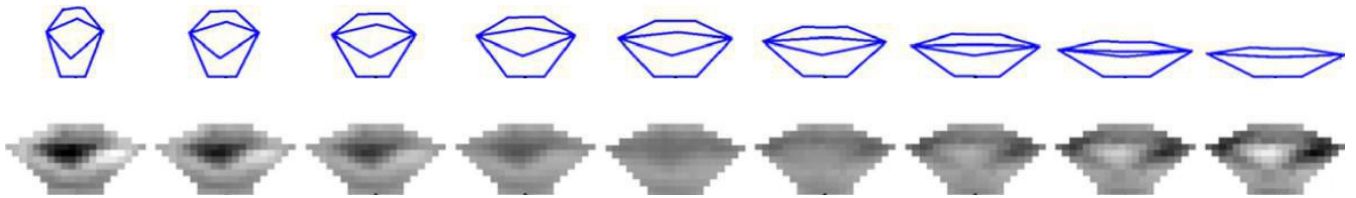


Mouth Modeling in ASLR

- Mouth features categorization:
  - Shape/Geometric measures: *[2,3] v. Agris et al.*
    [4] Nguyen et al.
    [5,6] Schmidt et al.



  - Appearance: *[1] Parashar*
    [7] Pfister et al.
  - Both: *[8,9] Koller et al.*
    [11,12] Antonakos et al.



Mouth Modeling in ASLR

- Recognition/Classification categorization:
  - Hidden Markov Model: *[2,3] v. Agris et al.*
    [4] Nguyen et al.
    [5,6] Schmidt et al.
    [8,9] Koller et al.
  - Support Vector Machine: *[4] Nguyen et al.*
    [7] Pfister et al.
  - Linear Discriminant Analysis: *[10] Benitez-Quiroz et al.*
  - Hierarchical Clustering: *[11,12] Antonakos et al.*

Mouth Modeling in ASLR

- Linguistic phenomena categorization:
  - Negation, Questions, Conditional/Relative clause, Assertions, Sign boundaries: *[1] Parashar*
    [4] Nguyen et al.
    [10] Benitez-Quiroz et al.
    [11,12] Antonakos et al.
  - Mouthings: *[5,6] Schmidt et al.*
    [8,9] Koller et al.
    [7] Pfister et al.

Mouth Modeling in ASLR

- SL categorization:
  - American: *[1] Parashar*
    [4] Nguyen et al.
    [10] Benitez-Quiroz et al.
    [11,12] Antonakos et al.
  - British: *[7] Pfister et al.*
  - German: *[2,3] v. Agris et al.*
    [5,6] Schmidt et al.
    [8,9] Koller et al.
  - Greek: *[11,12] Antonakos et al.*
- This is due to the existence of large annotated databases on these SLs.

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Challenges and Potentials

- Automatic analysis of mouth non-manuals is a very challenging problem
  - Occlusion by hands, intense mouthings, expressions and pose, tongue visibility, low resolution of the mouth region

(a) Occlusion (b) Mouthing (c) Tongue (d) Pose

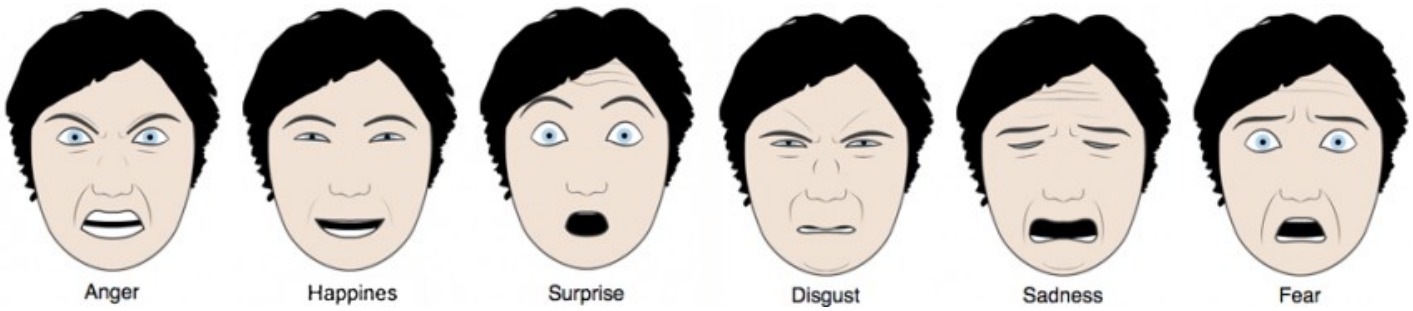
- It can be separated in two sub-problems:

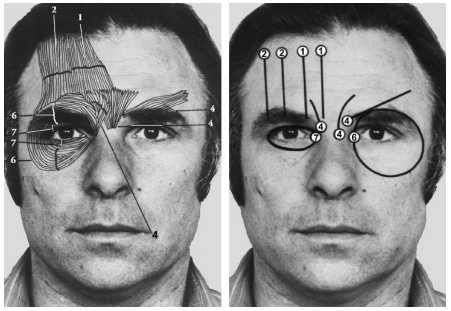
1) Automatic understanding of mouth-related expressions

2) Automatic understanding of mouthings

Automatic understanding of mouth expressions

- It can greatly benefit from the extensive research on Automatic Analysis of Facial Expressions.
- It involves two main lines of research:
  - Message judgment
    Recognize the meaning (emotion) conveyed with a facial expression (e.g. six basic emotions).
  - Sign judgment
    Recognize the physiological manifestation of a facial expression into its fundamental and, arguably, irreducible atoms, such as the movement of individual facial muscles (e.g. FACS).





Automatic understanding of mouth expressions

- Message judgment is not suitable for ASLR
  - Discrete set of predefined messages (expressions) that does not cover the full range of possible SL expressions.
  - There is no universal set of predefined SL expressions.
- Sign judgment is relevant to ASLR
  - Every possible facial expression can be comprehensively described as a combination of AUs.
  - AUs annotation is a hard task.

Automatic understanding of mouthings

- It can greatly benefit from the extensive research on Visual Speech Recognition.
- A viseme is a generic facial image that can be used to describe a particular sound (equivalent of phoneme in spoken language).
- Visemes and phonemes do not have one-to-one correspondence.
- There is existing research on representing visual speech data using latent variables.
- Viseme recognition is very challenging even for humans (reported error rate about 50%).

Conclusions

- Development of ASLR systems has the potential to support millions of Deaf people, as well as help linguists understand better SLs.
- ASLR has mainly concentrated on manual features.
- Recent research has shown that non-manuals (especially the mouth) play an important role.
- Very few papers attempt the fusion of manual and non-manual cues.
- Mouth modeling for ASLR can greatly benefit from the existing research in Facial Expressions Recognition and Visual Speech Recognition.

Thank you for your attention!