Hand in Hand: Automatic Sign Language to English Translation

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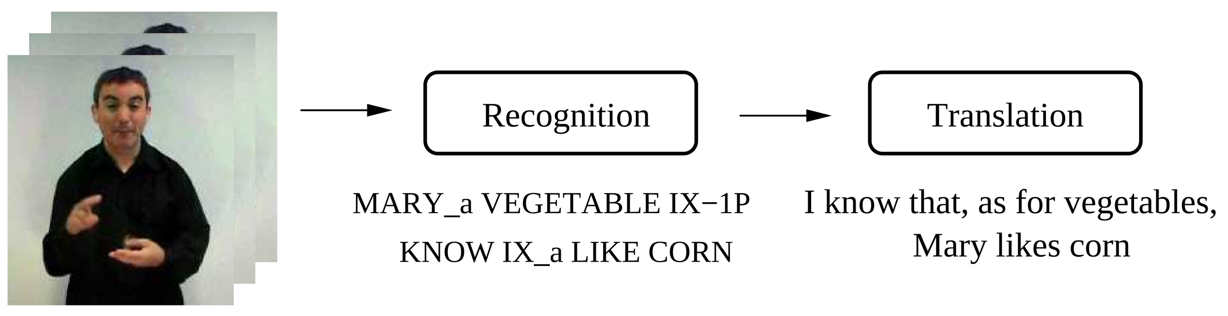
Introduction

- problem: all approaches in sign language research work on an intermediate language
- sign language in machine recognition:
  - input: video of signing person
  - output: semantic sign language representation (e.g. glosses)
- sign language in machine translation:
  - input: semantic sign language representation
  - output: written language (i.e. English)
- not directly intelligable by either hearing or deaf people
- incorporating statistical machine translation (SMT) on top of the recognition process:
  - converts glosses into written English
  - works even for very small corpora
  - data derived during the recognition can be used as additional knowledge source

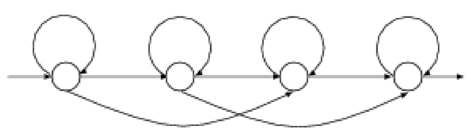
Intermediate Notation

- sign languages lack a formally adopted writing system
- syntactic representations describe handshape, location and movement of a sign
- glosses are a semantic representation of sign language
  - conventionally transcribed in the upper case stem form of the local spoken language
  - includes spatial and non-manual information

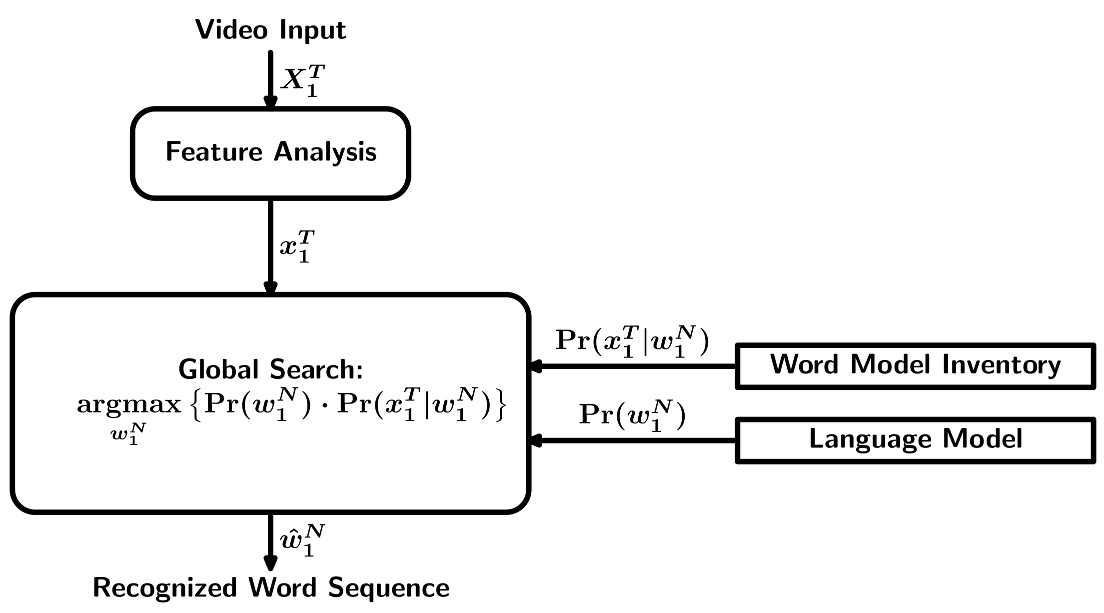


Sign Language Recognition

- a sign/gesture is a sequence of images
- important features
  - hand-shapes, facial expressions, lip-patterns
  - orientation and movement of the hands, arms or body
- HMMs are used to compensate time and amplitude variations of the signers



- goal: find the model which best expresses the observation sequence
- to classify an observation sequence X_1^T, we use the Bayesian decision rule:



Tracking

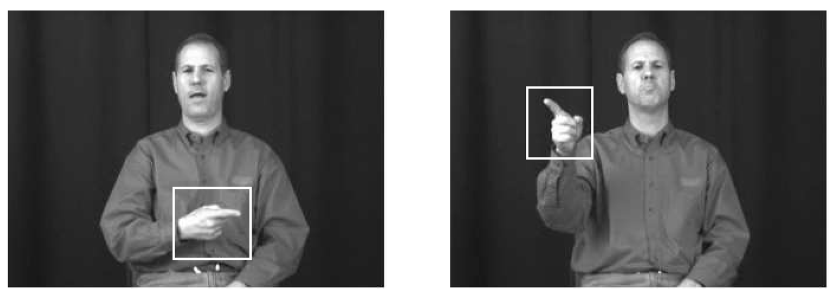
- tracking is done at the end of a sequence by tracking back the decisions to reconstruct the best path
- the best path is the path with the highest score wrt. a given scoring function

Sign Language Translation

- state-of-the-art phrase-based statistical machine translation system
  - for a recognized sequence f_1^J we maximize a translation probability for target sentences e_1^I
  - log-linear combination model:

$$p(e_1^I|f_1^J) = \frac{\exp\left(\sum_{m=1}^{M} \lambda_m h_m(e_1^I, f_1^J)\right)}{\sum_{\tilde{e}_1^I} \exp\left(\sum_{m=1}^{M} \lambda_m h_m(\tilde{e}_1^I, f_1^J)\right)}$$

  - set of different features h_m, scaling factors λ_m
  - trained with downhill simplex algorithm
- tracking positions of the sentences were clustered and their mean calculated
- for deictic signs, the nearest cluster according to the Euclidean distance was added as additional word information for the translation model

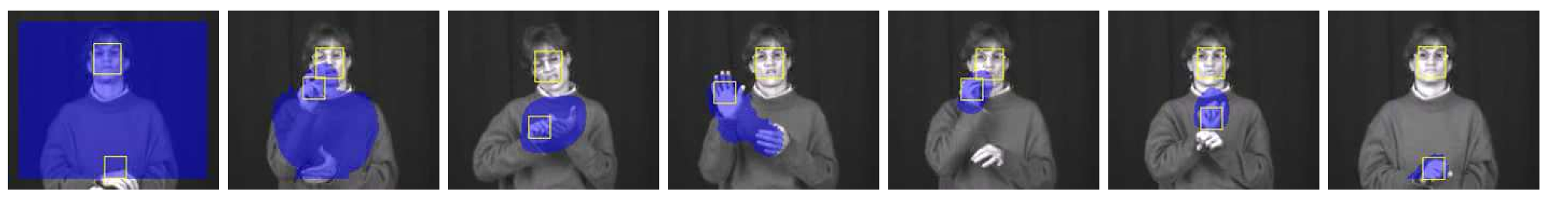


Experimental Results

- RWTH-Boston-104 database:
  - 161 training sentences, 40 test sentences

Experimental Results	WER[%]	PER[%]
recognition	17.9	-
translation	21.2	20.1
sign-to-speech	27.6	23.6

- RWTH-Boston-Hands database:
  - 1000 annotated frames, 2.3% tracking error rate
  - tracking of head and dominant-hand for ASLR



- enhancement with dominant-hand tracking features

Translation Features (different split)	WER[%]	PER[%]
without tracking	28.5	23.8
with tracking	26.5	23.5

Translation Example	
without tracking	John gives that man a coat
with tracking	John gives the man over there a coat.

Conclusion

- first data-driven automatic sign-language-to-speech translation system
- approach works for extremely small corpora typically encountered
- can be easily trained on new language pairs and new domains
- incorporation of the tracking data for the deictic words helps the translation system to discriminate between
  - distinctive article,
  - locative reference or
  - discourse entity reference

Outlook

- stemming of the glosses (i.e. leaving out the inflection)
- adding relevant features later in the translation
- model for all discourse entities
- handling spatial verb flexion, time information

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