Parsing N-Best Lists of Handwritten Sentences

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Introduction

The work presented in this talk addresses the task of recognition of general handwritten text.

- Offline recognition
- Large variation of writing styles and writing instruments
- Segmentation problem
- Lack of task-specific knowledge
- Large vocabulary

Introduction

The proposed parsing of n-best lists supports the following goals:

- Improvement of sentence and word recognition rate
- Production of parse trees
- Assignment of word tags (grammatical categories)

Resources

Handwritten sentence images

- Segmented IAM database
- Automatic extraction of sentences
- Generation of corresponding transcriptions

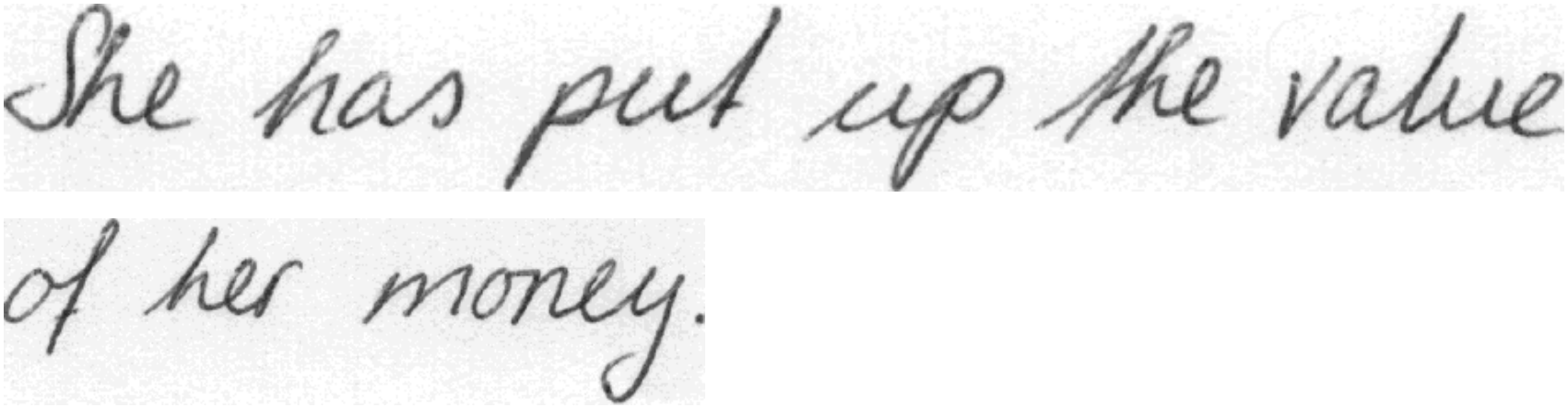
Linguistic resources

- Tagged LOB corpus for bigram models
- LPC for the stochastic context-free grammar, SCFG

IAM Database

- More than 1,500 scanned pages of handwritten text
- Material from over 600 different writers
  - 95,000 correctly segmented words
  - 13,000 lines of handwritten text
  - Over 5,000 complete sentences
- Covering a vocabulary of over 12,000 words

A Handwritten Sentence



She|has|put|up|the|value|of|her|money|.

Tagged LOB Corpus

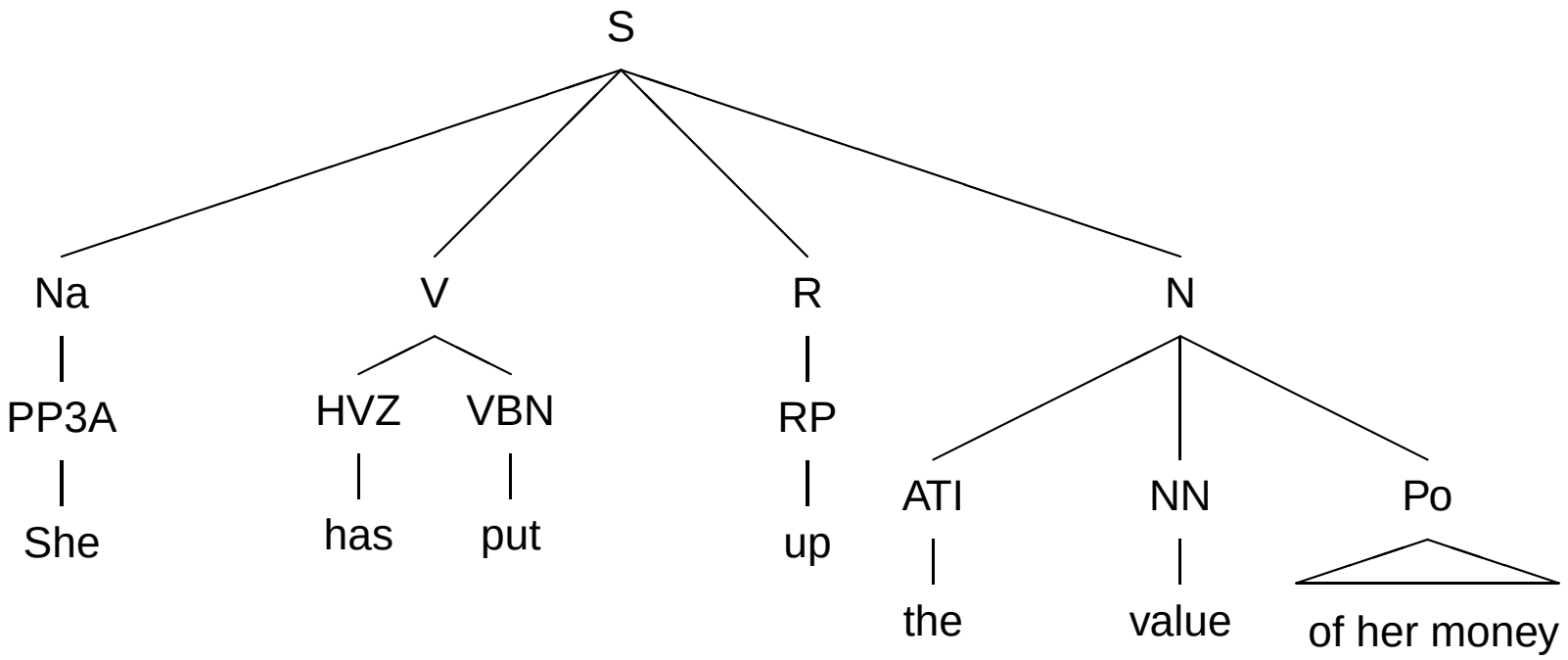
- Covers the LOB corpus
  - 1,000,000 word collection of British English text printed in 1961
  - 500 text samples of 2,000 words each
  - 15 text categories including press, general fiction, etc.
- Explicit segmentation of the text into words
- A grammatical tag is assigned to each word
- 167 tags are defined

Lancaster Parsed Corpus

- Covers a subset of 12,000 sentences from the LOB
- Parse trees in the form of bracketed sentences
- Only few long sentences
  - Average length 11.4 words
  - 19 words for the complete LOB

A Bracketed Sentence

$[S$ $[Na$ $[PP3A$ She $]][V$ $[HVZ$ has $][VBN$ put $]][R$ $[RP$ up $]][N$ $[ATI$ the $][NN$ value $][Po$ $[INO$ of $][N$ $[PP\$$ her $][NN$ money $]]]]]



Recognition of Handwritten Sentences

- Image normalization (skew, slant, position and height)
- Feature extraction (a sliding window)
- HMM for each character
  - Linear topology
  - Bakis modeling
  - Multi Gaussian
- Bigram language model
- Viterbi decoding

N-Best List

Rank	Score	Candidate sentence
1	23923.6	She has put up the value other money .
2	23921.8	She has put up the value of her money .
3	23890.3	She had put up the value other money .
4	23888.4	She had put up the value of her money .
5	23854.3	She has put up the value at her money .
...	...	...

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Parsing Sentences

- Parsing of SCFG
- Bottom-up chart parser based on CYK
- Early like elements
- Most probable parse
- Probability of most probable parse

Example Productions

Non-lexicalized rules

$$
\begin{array}{lcl}
\text{S} & \rightarrow & \text{Na V R N} \\
\text{Na} & \rightarrow & \text{PP3A} \\
\text{V} & \rightarrow & \text{HVZ VBN}
\end{array}
$$

Lexicalized rules

$$
\begin{array}{lcl}
\text{PP3A} & \rightarrow & \text{She} \\
\text{HVZ} & \rightarrow & \text{has} \\
\text{VBN} & \rightarrow & \text{put}
\end{array}
$$

Parse Probabilities

Rank	Parse Prb.	Candidate sentence
1	7.691e-23	She has put up the value other money .
2	4.629e-20	She has put up the value of her money .
3	2.631e-22	She had put up the value other money .
4	1.584e-19	She had put up the value of her money .
5	1.125e-21	She has put up the value at her money .
...	...	...

back

Combination Scheme

Recognition scores and parse probabilities are combined to a sentence score using the parse scale factor γ

$$recognition\ score + \gamma \log(parse\ probability)$$

the sentence score is used to reorder the n-best list

System	Top choice
Baseline	She has put up the value other money .
W. Parsing	She has put up the value of her money .

Experiments and Results

- 4,000 lines of text (30,000 words) to train the handwriting recognizer
- A closed vocabulary of 8,800 words
- The test set contains 67 sentences written by 52 individuals
- The SCFG contains 11,760 non-lexicalized productions
- The parse scale factor was optimized using six-fold cross-validation on the 67 sentences

Results

System	Sentence Rate	Word Rate
Baseline	4.6%	67.47%
With Parsing	6.0%	68.32%

- The improvement of the word recognition rate is significant on the 95% level
- For the correct sentences the tagging rate was 100%

Conclusions and Future Work

- A combination of a HMM based recognition system and a probabilistic bottom-up chart parser has been investigated
- A SCFG for general English text has been extracted from bracketed sentences
- By the incorporation of parse probabilities a significant improvement of the word recognition rate has been achieved
- A very high tagging rate for correct sentences was observed

Future Work

- Future work includes a a better training of the handwriting recognition module, the use of validation sets and larger test sets
- The probabilistic parsing of larger N-best lists will be investigated

Latest Results