Japanese Language Processing

Symbols and Formal Models

Petr Horáček

Department of Information Systems
Faculty of Information Technology
Brno University of Technology

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Outline

1. Processing *kanji* characters
   - Writing and character recognition
   - Character semantics and dependencies
   - Building a *kanji* database

2. Processing Japanese text
   - Natural language processing and formal models
   - Describing Japanese language
   - Specific problems

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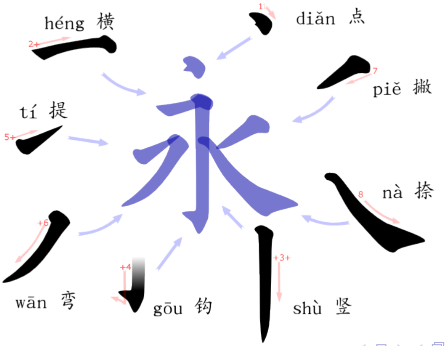
Writing *Kanji* Characters

- *Kanji* (漢字) are Chinese characters used in Japanese writing system.
- Each character is composed of several strokes.
- There are 8 basic strokes, shown in the chinese character *yong* (eternity) below.
- Several basic strokes can combine into one compound stroke.
- There is a given stroke order for writing each character.



Kanji Character Recognition

- Character recognition can be useful in many practical applications, such as:
  - Learning applications - Test if the user has learned to write the *kanji*.
  - Dictionaries - Even if the user is unfamiliar with Japanese, they may be able to redraw the character they want to look up.

Problem

- If we want to classify the character's image as a whole, there is too many classes (characters).

Solution

- If we have a vector representation of the character, we can recognize it by classifying the strokes and analyzing their relations (mainly positions) inside the character.
  - There is only a relatively small number of strokes.
  - The strokes can be easily distinguished.

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Kanji Character Semantics

- A single character typically has several readings, and can have more than one meaning.
- Readings are divided into 2 groups:
  1. *On'yomi* (音読み) - Sino-Japanese reading, a Japanese approximation of a Chinese pronunciation. Used mostly for compound words (consisting of more than one *kanji*).
  2. *Kun'yomi* (訓読み) - Japanese reading, based on a native Japanese word with a similar meaning. Used mostly for stand-alone *kanji* characters.

Example

Character	*On'yomi*	*Kun'yomi*	Meanings
行	KOU, GYOU コウ，ギョウ	iku, yuku い(く)，ゆ(く)	to go

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Kanji Character Dependencies

- A sequence of *kanji* characters (usually 2, but it can be more) can form a compound word with a new meaning.
- This also determines the readings of the *kanji* in the compound word.

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Character	Readings	Meanings	Compounds
日	NICHI, JITSU ニチ，ジツ hi, ka ひ，か	the sun day	ある日 *aruhi* - one day 毎日 *mainichi* - everyday 今日 *kyou* (irregular) - today 日曜日 *nichiyoubi* - Sunday
学	GAKU, KAKU ガク，カク manabu まな(ぶ)	learning science to learn	科学 *kagaku* - science 学校 *gakkou* - school 数学 *suugaku* - math

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Building a *Kanji* Database

The minimal information that we need to maintain for each character contains:

1. Readings
   - We should distinguish between *kon'yomi* and *on'yomi*
2. Meanings
3. Relations and dependencies to other characters
   - Compounds
   - Radicals
4. Graphical representation
   - Preferably vector-based

Character relations are very important, since they affect the characters' readings and meanings.

- Create a relational model?
- Implement as a relational database (SQL. . .)?

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Natural Language Processing and Context-Free Grammars

- Formal models practically used in natural language processing (NLP) are often based on context-free grammars.

Definition

A context-free grammar (CFG) is a quadruple $G = (N, T, P, S)$, where

- N is a finite set of *nonterminal* symbols
- T is a finite set of *terminal* symbols, $N \cap T = \emptyset$
- P is a finite relation from N to $(N \cup T)^*$, usually represented as a finite set of *rules (productions)* of the form

  $$A \rightarrow x,$$

  where $A \in N$ and $x \in (N \cup T)^*$
- $S \in N$ is the *start symbol*

Context-Free Grammar

Derivation

1. Let $G = (N, T, P, S)$ be a CFG. Let $u, v \in (N \cup T)^*$ and $p = A \rightarrow x \in P$. Then, uAv *directly derives* uxv according to p in G, written as $uAv \Rightarrow_G uxv \; [p]$ or simply $uAv \Rightarrow uxv$.
2. The relation $\Rightarrow^*$ *(derives)* is the reflexive transitive closure of $\Rightarrow$.

Generated language

Let $G = (N, T, P, S)$ be a CFG. The *language generated by* G, denoted as $L(G)$, is defined as

$$L(G) = \{w : w \in T^*, S \Rightarrow^* w\}$$

Beyond CFG

Problem

- CFG by itself has insufficient generative power to describe a natural language (natural languages are generally not context-free).
- Context-sensitive (Type-1) and general (Type-0) grammars are not suitable for practical implementation.

Solution

- Increase the generative power without significantly increasing the implemenatation cost. (Find "something between" CF and CS?)
- New models are often based on CFG (or context-free rules).
  - Common in NLP: CCG (using combinatory logic), PCFG/SCFG (probabilistic CFG, using statistical approach), LTAG (rewriting tree nodes instead of symbols)...
  - Other: matrix grammar, random context grammar, programmed grammar, scattered context grammar...

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Matrix Grammar

Definition

A matrix grammar is a pair $H = (G, M)$, where

- $G = (N, T, P, S)$ is a context-free grammar
- M is a finite language over P $(M \subseteq P^*)$

Notation

- Let $N = A_1, \ldots, A_m$ for some $m \geq 1$
- For some $m_i = p_{i_1} \ldots p_{i_j} \ldots p_{i_{k_i}} \in M$,

$$p_{i_j} : A_{i_j} \rightarrow x_{i_j}$$

Matrix Grammar

Derivation step

For $x, y \in (N \cup T)^*$, $m \in M$,

$$x \Rightarrow y[m]$$

in H if there are $x_0, \ldots, x_n$ such that $x = x_0, x_n = y$, and

1. $x_0 \Rightarrow x_1[p_1] \Rightarrow x_2[p_2] \Rightarrow \cdots \Rightarrow x_n[p_n]$ in G, and
2. $m = p_1 \ldots p_n$

Generated language

$$L(H) = \{x \in T^* : S \Rightarrow^* x\}$$

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Describing Japanese Language

- Japanese sentences are in the SOV (subject-object-verb) form.
  - English, for example, uses SVO.
- Consider a CFG G with the following rules (nonterminals are in capital letters):

1:	S	$\rightarrow$	SP OP VP	5:	NP	$\rightarrow$	N
2:	SP	$\rightarrow$	NP *wa*	6:	N	$\rightarrow$	*kore* | *daigaku*
3:	OP	$\rightarrow$	NP	7:	V	$\rightarrow$	*desu*
4:	VP	$\rightarrow$	V				

- One of the possible derivations is:
  S $\Rightarrow$ SP OP VP $\Rightarrow$ NP *wa* OP VP $\Rightarrow$ N *wa* OP VP $\Rightarrow$ N *wa* NP VP $\Rightarrow$ N *wa* N VP $\Rightarrow$ N *wa* N V $\Rightarrow$ *kore wa* N V $\Rightarrow$ *kore wa daigaku* V $\Rightarrow$ *kore wa daigaku desu* ("this is an university")
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Forming Questions

- To change a statement into a question, we can simply append *ka* at the end of the sentence.
- We can add the following rule to G:

$$8: \quad \text{VP} \quad \rightarrow \quad \text{V } \textit{ka}$$

- Derivation example:
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- Adding the following 2 rules to G:

$$9: \quad \text{OP} \quad \rightarrow \quad \text{INT} \quad | \quad 10: \quad \text{INT} \quad \rightarrow \quad \textit{nan}$$

  allows us to generate: S ⇒ SP OP VP ⇒ NP *wa* OP VP ⇒ N *wa* OP VP ⇒ N *wa* INT VP ⇒ N *wa* INT V *ka* ⇒ *kore wa* INT V *ka* ⇒ *kore wa nan* V *ka* ⇒ *kore wa nan desu ka* ("what is this?")

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- To change a statement into a question, we can simply append *ka* at the end of the sentence.
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- Consider a matrix grammar $H = (G, M)$ with the following rules in G (nonterminals are in capital letters):

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  and $M = \{(1), (2), (3), (4), (5), (6), (7), (8), (9, 8), (10)\}$

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Outline

1. Processing *kanji* characters
   - Writing and character recognition
   - Character semantics and dependencies
   - Building a *kanji* database
2. Processing Japanese text
   - Natural language processing and formal models
   - Describing Japanese language
   - Specific problems

Specific Problems

- Besides *kanji*, the Japanese writing system also uses 2 syllabaries:
  1. *Hiragana* (ひらがな) - used for particles, suffixes. Also can be used for words that have no *kanji*, or if the *kanji* is not known to the writer. It is also possible to write Japanese text entirely in *hiragana* (without using *kanji*; this is common in children's books, japanese textbooks for beginners etc.)
  2. *Katakana* (カタカナ) - used mainly for transcribing words from foreign languages (including names).
- Modern Japanese writing sometimes also includes Latin alphabet (mostly abbreviations) and roman numbers.
- The transcription of Japanese text using Latin alphabet is called *romaji* (ローマ字). There are several different standards.
- In Japanese sentences, it is not customary to separate words by spaces.

Specific Problems

Example

- A typical Japanese sentence might look like this:
  日本とチェコスロバキア間の外交関係は
  1919年に樹立されました。
  ("The diplomatic relations between Japan and Czechoslovakia started in 1919.")
- However, it is also possible to write it in *hiragana* only:
  にほんとちぇこすろばきあかんのがいこうかんけいは
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References

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