COMPUTATIONAL ANALYSIS OF MANDARIN SOUNDS
WITH REFERENCE TO THE ENGLISH LANGUAGE

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In the analysis of Mandarin, the author used a
corpus composed of over 750,000 samples transcribed
automatically from Chinese characters by the com-
puter through the sequential application of a set
of phonetic rules developed by the author. The
result is a classification and rank distribution
of all speech sounds, the phonetic properties,
frequency distribution of symbols, phonemes, syl-
lables, tones, and their combinations. These
statistical properties are compared with those of
the English language.

INTRODUCTION

English is widely used throughout the world while Mandarin is spoken
in China by one quarter of the world's population. It is interest-
ing to compare the phonetic properties of these two languages and to
study their similarities and differences to understand the problems
involved when the speakers of one language learn to speak the other
language.

The linguistic aspects of written English and Chinese, such as those
presented below, have already been studied extensively (see Suen
(1979 a & b)), e.g. a) the frequency of occurrence of words/
characters, b) the statistical distribution of letters/radicals,
and their combinations, c) the study of syntax, semantics, prag-
matics, and related areas, and d) translation of one language into
another. Also the linguistics aspects of spoken English have been
described in well-known literature (Dewey (1923), Carterette et al
(1974)), e.g. a) the frequency of occurrence of syllables, b) the
statistical distribution of phonemes and their combinations, c) the
phonetic system and symbolic representation of sounds, and d) a-
coustical analysis, recognition and synthesis of the spoken language.
Such investigations, however, have been rarely conducted on Mandarin,
the official language spoken in China, owing to many reasons. In
order to close this gap, the author has initiated several research
projects aimed specifically at the analysis of these aspects (Suen
(1979 b)).

PROPERTIES OF MANDARIN

Mandarin sounds consist of consonants, vowels, semi-vowels and diph-
thongs. A Mandarin syllable comprises 1 to 3 such constituents, the
first symbol is usually a consonant. The syllabic structure of
Mandarin is shown below. A key to the phonetic symbols used in this

paper can be found in Suen (1979 b).

Syllabic Structure	Example
1. Vowel	/A/
2. Diphthong	/EI/
3. Triphthong	/I AU/
4. Vowel + Nasal	/AN/
5. Diphthong + Nasal	/I ANG/
6. Consonant + Vowel	/B O/
7. Consonant + Diphthong	/P AU/
8. Consonant + Triphthong	/M I AU/
9. Consonant + Vowel + Nasal	/R UN/
10. Consonant + Diphthong + Nasal	/L I ANG/

Associated with each Mandarin syllable is a tone which gives the musical quality. It is normally denoted by a diacritical mark as shown below. A tone specifies the pitch contour of the syllable. There are five tones in Mandarin and they can be described as follows (Suen (1979 b)):

Tone	Description	Pitch
1. ⎺	high level	55
2. ╱	high rising	35
3. ∨	low rising	214
4. ╲	high falling to low	51
5. •	neutral	5

For example, the syllable /WO ∨/, meaning "I" in English, has a low rising tone. Since there are only about 400 different syllables in the whole Mandarin language, the tone is crucial in signifying the meaning of words. This property of Mandarin is distinct from the English sounds.

COMPUTATIONAL ANALYSIS OF DATA

In computational linguistics, it is essential to have a large collection of data in order to derive reliable results. The help of a

computer is indispensable. In this study, computational analysis of a corpus composed of more than 750,000 samples of Mandarin syllables was made. More details .can be found in Suen (1979 b). Owing to the limitation of space here, this paper only compares the frequency distribution of Mandarin and English phonemes. The distribution of English sounds was derived from a study conducted by Carterette and Jones (1974). Their phonemic frequencies were obtained from a transcription of 15,694 words spoken by 24 subjects.

REMARKS ON MANDARIN/ENGLISH SOUNDS

From Tables 1 and 2, one can make the following observations:

(a) Mandarin consonants occur 8% less frequently than English consonants

(b) Semi-vowels are used twice more often in Mandarin than in English

(c) Vowels occur more frequently in Mandarin than in English

(d) Chinese speakers used diphthongs more often than English speakers

(e) Mandarin tones are not evenly distributed and the 4th tone occurs much more frequently than the others

(f) Although both English and Mandarin have approximately 40 phonemes, many Mandarin phonemes do not occur in the English language, especially the retroflex and dental sibilant sounds, and the round-lipped vowel ü which occur rather frequently (about 12%) in Mandarin conversations

(g) There is considerable difference in the distribution of Mandarin and English diphones, triphones, etc. which affect significantly the formation of syllables in these two languages

(h) Considerable difference also occurs between the syllabic structures of English and Mandarin

(i) There are many more sound patterns in English (about one distinct sound for one word) than in Mandarin (only about 1160 distinct sounds in the entire language)

Implications of the above on the learning of Mandarin by English speakers will be discussed. Their effects on computer synthesis and recognition of Mandarin speech will also be presented. If time permits, the author wishes to present his new phonetic system which will enable an English speaker to pronounce Mandarin sounds correctly and easily. Encouraging results of applying this new system in the learning situation will be discussed.

Table 1

Relative Percent Proportion of Phonemes in the Corpus: Classified
into Consonants, Semi-vowels, Vowels and Diphthongs.

(a)   Consonants

Manner / Place	Plosive		Nasal	Lateral	Fricative	Total
	Unaspirated	Aspirated				
Labial	b 1.97	p 0.40	m 1.49		f 1.03	4.89
Dental & Alveolar	d 4.00	t 1.61	n 7.60	l 2.24		15.45
Gutteral	g 1.91	k 0.78	ŋ 6.10		h 1.98	10.77
Palatal	ǰ 2.56	č 1.23			ɕ 2.13	5.92
Retroflex	dẓ 2.11	tʂ' 1.04			ʃ 3.13 ʐ 0.78	7.06
Dental Sibilant	dz 1.38	ts' 0.45			s 0.86	2.69
Total	13.93	5.51	15.19	2.24	9.91	46.78

(b)   Semi-vowels

w 4.52	y 3.86	Total 8.38

(c)   Vowels

Tongue Position	Front	Central	Back	Total
High	i 12.45 ü 1.91		u 4.43	18.79
Mid	ɛ 3.15	ɜ˔ 0.40 ə 6.19	ɔ 1.93	11.67
Low		a 6.67		6.67
Total	17.51	13.26	6.36	37.13

(d)   Diphthongs

ai 1.69	ei 1.75	au 2.23	ou 1.43	iu 0.60	Total 7.70

(e)   Tones

1st Tone	2nd Tone	3rd Tone	4th Tone	5th Tone
21.39	20.40	17.75	34.46	6.01

Table 2
Relative Percent Frequency Occurrence of Phonemes in English Speech.

(a) Consonants

Manner / Place	Plosives Voiced	Plosives Un-Voiced	Nasal	Lateral	Fricatives Voiced	Fricatives Un-Voiced	Total
Labial	b 1.80	p 1.43	m 2.46				5.69
Labial-Dental					v 1.52	f 1.42	2.94
Dental					ǯ 2.78	θ 0.80	3.58
Alveolar	d 3.75	t 4.62	n 7.11	l 3.80 r 5.76	z 2.27	s 4.65	31.96
Palatal	ǰ 0.82	č 0.44			ʒ 0	ʃ 0.45	1.71
Velar	g 1.23	k 2.90	ŋ 1.06				5.19
Glottal		ʔ 2.03				h 1.63	3.66
Total	7.60	11.42	10.63	9.56	6.57	8.95	54.73

(b) Semi-Vowels

w 2.87	y 1.93	Total 4.80

(c) Vowels

Tongue Position	Front	Central	Back	Total
High	i 3.77 I 5.11		u 1.78 ʊ 0.47	11.13
Mid	e 1.55 ɛ 3.18	ə 12.99	ɔ 1.51	19.23
Low	æ 2.52	a 1.22		3.74
Total	16.13	14.21	3.76	34.10

(d) Diphthongs

aᴵ (bite) 3.19	aᵁ (bout) 0.75	oⁱ (boy) 0.09	oᵁ (boat) 2.34	Total 6.37

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