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ABSTRACT

Measurement of the mutual intelligibility of dialects of a language is discussed. The focus is on several theoretical constructs in measurement, illustrated with data from an earlier study of the mutual intelligibility of 17 Chinese dialects. Measurement procedures are also explained. It is proposed that mutual intelligibility is based on the ability to categorize things and recognize patterns, and that phonological correspondences between source and target dialects fall into two categories: common (communication signals) and less common (noise interference). Further, these patterns of correspondence (signal and noise) can be weighted according to the characteristics of their occurrence. Computation of indexes of mutual intelligibility using these weightings, made at the level of the syllable-word in Chinese, is explained. Appended materials include: calculations for the mutual intelligibility of initial consonants, vowels, endings, and tones of two Chinese dialects, those of Beijing and Jinan; a chart illustrating degree of dialect affinity of 17 Chinese dialects based on mutual intelligibility; a chart illustrating dialect affinity based on genetics relations of initials, finals, and tones. Contains 29 references. (MSE)

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ABSTRACT

It is assumed that to a large extent human pattern cognition is based on the observation of repeated phenomena. Repetition lends its weight of numbers to pattern formation. For a speaker of one dialect to understand the speech of another, linguistic correspondence patterns for the two dialects have to be established. By quantifying the patterns, one can speak of the degree of mutual intelligibility. Much of the space of this paper is devoted to discussions of the view point of correspondence patterns, the concepts of source dialect, target dialect, signal, and noise, and the weight scale proposed to quantify the level of signal and noise of correspondence patterns. As an example of the intelligibility computation based on phonology, over 2,700 syllable-words in the *Hanyu Fangyin Zihui* (Beijing University 1962, 1989) were used to calculate the intelligibility degrees for all the pairs of the 17 dialects contained therein. The degrees of intelligibility for all the dialect pairs are used in cluster analysis to establish a grouping of dialects.

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QUANTIFYING DIALECT MUTUAL INTELLIGIBILITY

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As students of language we were often asked the question "how different are Chinese dialects?" In the past, our standard answer to questions of this sort was to give a classification of the dialects. For example, we would say that Beijing belongs to Mandarin and Xiamen belongs to Southern Min. To a layman, that answer did not make much sense. So the follow-up question was usually the following: "Are they mutually intelligible?" At that point, we were as lost as the layman. How could we talk about dialect similarity and mutual intelligibility?

Traditionally, dialects are classified in terms of qualitative differences of language characteristics. The characteristics may be represented by isoglosses -- lines connecting places that have identical entities. They may be stated as rules, either synchronic or diachronic. They may be summarized as presence or absence of certain features. For example, from the point of view of the existence of voiced obstruent initials, we may put Suzhou of Jiangsu and Shuangfeng of Hunan in one group and other varieties of Chinese in another. If we focus on the presence or absence of the consonantal ending of the syllable, then Shuangfeng and Beijing can be grouped together and Suzhou has to be put in a different class with some other dialects. But then, how do we arrive at an overall classification of Chinese dialects? We often rely on the relative importance of features. So we claim that some features are more important than others, and use the important ones to establish a grouping. How do we determine the important weight of features? Decisions can be made on the basis of personal qualitative judgments, which can be subjective. If we wish to achieve the objective of expressing things in terms of verifiable measurements, then we need to quantify the weight of the characteristics. Over the past 70 years the Chinese linguistics community has cumulated sufficient dialect data to allow for measurements of linguistic matters. As the large amount of data is becoming information overload, we need to make some meaningful synthesis. Indeed, as Wang (1991:3) puts it, "the real intellectual rewards come from the theoretical interpretations of these data." In the past few years, quantitative studies have contributed to the discussion of measurement methodologies and brought to light several new issues in linguistics.

A very brief review of the methodologies and issues may be in order. Measurements of linguistic similarities existed long ago. Kroeber and Chretien (1937) and Reed and Spicer (1952) used correlation methods to quantify language distance. In the 1950's glottochronological studies focused on the particular issue of time-depths of languages. Wang (1960) was the first attempt to apply such a lexicostatistical method to determine linguistic relationships among five Chinese dialects. However, only in the late 1970's and early 1980's more systematic investigations of dialect affinity using modern computer technology with a vast amount of data began to appear. My initial formulations of affinity inquiry (Cheng 1982, 1986, 1987, 1988, 1991) have been improved by several in-depth studies. Ogura (1990) and Wang (1987) also use similarity measurements of some sorts to compute numerical indices of language affinity. Essentially, the affinity measurements are based on the ratio of shared items to the total number of items considered. The items may be lexical entries, phonological elements, or other entities, but they all exist in morphemes or words. Lu and Cheng (1985) further state that words are carriers of sound change and that a large quantity of them used in deriving the numerical indices of dialect correlation will account for the weight or importance of features. However, as each investigation has its own focus, selection of characteristics becomes restricted and the weight problem is further complicated. For example, Wang and Shen (1992) state simply that the first step in determining numerical taxonomy is selection of characteristics. The statistical question of sample versus population needs more discussion than has been presented so far. On the other hand, the Pearson correlation method that I originally used has been shown to have a tendency to inflate the weights of the features that are absent in the pair of dialects in question and are included to account for other pairs. Ma (1989), Tu and Cheng (1991), and Wang and Shen (1992) have all discussed this issue and have come to favor the use of Jaccard's coefficient, which excludes the non-occurring features in the computation. Another area of concern is the tabulation of words without regard to their sharing of internal structures or morphemes. In Cheng (1986, 1991) I mention the need for a finer treatment of "word family". Wang and Shen (1992) has presented a way to tabulate all the morphemes within words in their quantification process and thus give more appropriate weights to such elements as prefixes, suffixes, and reduplication. Regarding dialect studies, the geographical areas that have more varied dialectal differences especially need quantitative measurements to establish affinity. For example, Lu (1991), and Wang and Shen (1992) deal with the Wu-dialect area, and Lu (1986) and Yang (ms) cover certain Min dialects. Quantitative studies of affinity are gathering momentum.

The other aspects of the questions that were often posed by the layman have to do with how we calculate language mutual intelligibility. As far as I know, language mutual intelligibility has not been well studied. In the past, the notion of mutual intelligibility was used only loosely in language classification. Yet it played an important role in determining how languages or dialects were related. For example, in field work we usually asked our subjects if they could communicate with those in their neighboring communities. We often used the information so obtained to make statements of dialect relationships.

The affinity measurements mentioned above are similarity measurements. In my view, mutual intelligibility involves not only similarity of elements but also the patterns of correspondence between two dialects. I therefore feel that it is not entirely appropriate to interpret similarity as mutual intelligibility. In the early 1950's, Voegelin and Harris (1951), Hickerson, Turner, and Hickerson (1952), and Pierce (1952) asked their subjects to listen to recorded passages and counted the percentage of correct scores as the degree of mutual intelligibility. These subjective tests yield subjective results varying according to the linguistic experience of the subjects. I feel that a more systematic measurement is required to obtain mutual intelligibility.

A couple of years ago, I (Cheng 1990) ventured to compute mutual intelligibility indices for the 17 dialects given in the *Hanyu Fangyin Zihui* (Beijing University 1962, 1989). The methodology, computational procedures, and results are given in Cheng (1992). The main theme of that paper was that mutual intelligibility could be studied in terms of language as a system (systemic mutual intelligibility) and in terms of individuals' ability and experience (participant mutual intelligibility). The speaker-based intelligibility should have its base in the systemic intelligibility. The paper dealt with systemic matters only. Systemic mutual intelligibility was calculated according to the correspondence patterns between the dialects in question. While correspondence patterns of all linguistic components should be considered to derive an overall picture of mutual intelligibility, as an initial step in this endeavor, the correspondence patterns examined in that paper were those of the initials, medials, main vowels, endings, and tones of Chinese syllable-words. Some correspondence patterns can enhance while others may interfere with communication. Therefore the notions of signal and noise were defined so as to determine the contribution of the patterns to intelligibility. A weight scale was proposed to compute the values of signal and noise patterns. The intelligibility degree was then obtained from the sum of the values for all the patterns divided by the total number of elements considered.

As much of the space of that writing is devoted to discussion of the procedures to obtain mathematical precision and of the results to show the usefulness of the quantitative method, many concepts involved in calculating mutual intelligibility need to be further discussed. This paper will therefore deal in greater detail with the theoretical constructs of category cognition, signal and noise, and weight of elements. Naturally, in the discussion the measurement procedures will be reiterated.

1. Number, Category, and Cognition

The basis of my analysis of mutual intelligibility is our ability to categorize things around us. As we see events happening with repetition, we find patterns of occurrence. The patterns then help us put things or events together or in separate entities and thus allow us to form categories. Categories in turn are the units that help shape human cognition. Dialect communication, in my view, follows the same cognition process. Let us take Beijing and Jinan as examples to illustrate the point.

Let us first examine the pronunciations (tones being omitted) of the following cognate words in Beijing (given first) and Jinan, :

(1)	a.	nye	ye	'to abuse'
	b.	nən	luẽ	'delicate'
	c.	na	na	'to receive'

d.	ni	ɲi	'mud'
e.	niau	suei	'urine'

For now, let us look at the initials. We see that the dental nasal in Beijing corresponds to the zero initial, the lateral, the dental nasal, the palatal nasal, and the dental fricative in Jinan. From these data we do not see any patterns. If they were the only words in the Beijing dental nasal category, then we would have to memorize the one-to-one sound correspondence individually. However, of the more than 2,700 words in the *Hanyu Fangyin Zihui* there are 53 words pronounced with the dental nasal in Beijing. The occurrences of their cognate counterparts in Jinan show the following patterns, the number indicating the amount of words occurring in each correspondence:

(2)	a.	n	zero	3
	b.	n	l	1
	c.	n	n	27
	d.	n	ɲ	21
	e.	n	s	1

As the initials of the 53 words fall into five categories, we have a fuller picture of the correspondence of sounds in these two dialects. Of these five patterns we find two types in terms of occurrence: the minor type of the patterns for 1, 1, and 3 words and the major type of the patterns for 27 and 21 words. The meanings of majority and minority here are straightforward. Occurrences with a small number of words are of the minor type, and occurrences with a large number of words are of the major type. We can better define these terms by using the mean as the reference point and say that minority is the occurrence smaller than the mean and majority is the occurrence equal to or greater than the mean. This definition is again straightforward, and it seems reasonable since we often deal with matters using the mean as the reference point. The implication here is that the mean is considered to represent a psychological level at which point certain aspects of human cognition change more markedly.

In (2) we have a total of 53 words occurring in five patterns. The mean is 10.6. Now we can restate the two types of correspondence patterns by saying that those whose occurrences are smaller than the mean of 10.6 are the minority and those whose occurrences are greater than 10.6 are the majority. A major correspondence covers relatively many words and th ore provides the speaker of one dialect much information about the corresponding sound in the other dialect in question. Once such a knowledge is gained, dialect communication is possible. On the other hand, since minority patterns contain a small number of words, one needs to spend extra efforts in learning the individual entities which do not behave as expected. Therefore we consider majority patterns as communication signal enhancement and minority patterns as noise interference.

The correspondence patterns in (2) now take on an additional attribute of signal or noise depending on whether their occurrence is smaller or greater than the mean as given in (3):

(3)	a.	n	zero	3	10.6	noise
	b.	n	l	1	10.6	noise
	c.	n	n	27	10.6	signal
	d.	n	ɲ	21	10.6	signal
	e.	n	s	1	10.6	noise

Now we have three noise and two signal correspondence patterns regarding the dental nasal of Beijing with respect to Jinan. As signal and noise give different effects to dialect communication, we can use them to establish a weight scale to calculate mutual intelligibility. However, at this juncture we need to review another aspect of the correspondence patterns given above and discuss the notions of "source dialect" and "target dialect".

2. Source and Target Dialects

The patterns in (3) are formed on the basis of the dental nasal initial of Beijing. When the dental nasal initial of Jinan is used as the basis for its correspondence to Beijing pronunciations, the patterns will be different. In fact there is only one pattern as given in (4):

(4)	n	n	27	27.0	signal

All the words with a dental nasal initial in Jinan are pronounced with a dental nasal initial in Beijing. The number of words involved is 27, and the mean is 27.0. Therefore this pattern is considered signal.

As we see the difference between the patterns listed in (3) and that in (4), we recognize the unidirectional nature of the correspondence patterns. We therefore need to state the basis of the correspondence. In another word, the patterns in (3) are those from the point of view of the Beijing dental nasal and that in (4) is the pattern from the point of view of the Jinan dental nasal. Thus we may say that Beijing is the "subject" or "source" dialect and Jinan the "object" or "target" dialect in (3). On the other hand, in (4) Jinan is the source dialect and Beijing the target dialect. Thus as we build the patterns into the formula for calculating intelligibility, we will also need to recognize the directionality of intelligibility.

Mutual intelligibility of a pair of dialects will be computed from the two numbers of unidirectional intelligibility of the dialects. This will be further discussed later.

The terms "source" and "target" here refer to how the patterns of correspondence are arranged and not necessarily to the view point of the speaker in actual communication. At this point we are arguing for the recognition of unidirectional intelligibility. That is, the correspondence patterns have to be considered both from the elements in one dialect and from those in the other. I realize that although the concepts are simple, these terms are not the most descriptive. In Cheng (1990, 1992) the words "subject" and "object" were used for these concepts; here we have chosen "source" and "target" as a wording alternative. As we study intelligibility more in the future we may be able to refine the concepts and find better words for them.

3. Weight Scale

So far we have shown that our attempt to quantify mutual intelligibility differs considerably from measurements of language similarity as discussed at the beginning of this writing. We have also departed from the measurements of understood points in subjective tests as first carried out by Voegelin and Harris (1951), Hickerson, Turner, and Hickerson (1952), and Pierce (1952) mentioned earlier. The thrust of this paper is that similar elements in a pair of languages can carry different weights in communication. The weights are determined on the basis of whether a pattern is considered signal or noise.

We assume that signal patterns enhance communication and noise patterns reduce intelligibility. To quantify the differences of these two types of patterns, we may assign tentatively the unit value of 1 to signal and -1 to noise as a first approximation. To calculate the unidirectional intelligibility of dialects A and B with dialect A as the source dialect, we first tabulate all the correspondence patterns from the viewpoint of the elements in dialect A. Then for each pattern we calculate the value by multiplying the number of elements occurring in the pattern by the unit value 1 (if signal) or -1 (if noise). The sum of the values thus obtained divided by the total number of the elements considered is the unidirectional intelligibility.

However, in many cases the uniform value of noise does not seem to capture how we feel about the extent of interference or confusion. For example, in (3) we see that the dental nasal of some words in Beijing are pronounced with the zero initial in Jinan. And Beijing has other, non-cognate, words with the zero initial. Thus the zero initial of the words in Jinan could be incorrectly interpreted as belonging to the Beijing zero-initial word class. Similarly, the Jinan lateral in (3) could be incorrectly interpreted as the lateral in Beijing. With regard to signal, some differentiation is also needed. For example, in (3) the 27 words pronounced with the dental nasal in Jinan are pronounced with the identical initial. In this case, there is no possibility of confusion. On the other hand, even though the pattern of the dental nasal corresponding to the palatal nasal is signal, the palatal nasal does not exist in Beijing. We feel that additional parameters are required to interpret the correspondence. Thus the patterns in (3) have to carry with them additional caveats as given in (5):

(5)	a.	n	zero	3	10.6	noise	different	zero occurs elsewhere in Beijing
	b.	n	l	1	10.6	noise	different	l occurs elsewhere in Beijing
	c.	n	n	27	10.6	signal	same	
	d.	n	ɲ	21	10.6	signal	different	ɲ does not occur in Beijing
	e.	n	s	1	10.6	noise	different	s occurs elsewhere in Beijing

In addition to the signal and noise types given in (5) we found others in the Beijing-Jinan correspondence patterns in (6), (7) and (8). The patterns in (8) are for tones transcribed in the five-point notation.

(6)	a.	ʐ	zero	2	15.0	noise	different	zero occurs elsewhere in Beijing
	b.	ʐ	l	18	15.0	signal	different	l occurs elsewhere in Beijing
	c.	ʐ	ʐ	25	15.0	signal	same	

(7)	a.	s	ɕ	5	19.5	noise	different	ɕ occurs elsewhere in Beijing
	b.	s	ɲ	1	19.5	noise	different	ɲ does not occur in Beijing
	c.	s	s	65	19.5	signal	same	
	d.	s	ʂ	7	19.5	noise	different	ʂ occurs elsewhere in Beijing

(8)	a.	55	213	668	171.5	signal	different	213 does not occur in Beijing
	b.	55	42	9	171.5	noise	different	42 does not occur in Beijing
	c.	55	55	5	171.5	noise	same	
	d.	55	21	4	171.5	noise	different	21 does not occur in Beijing

The occurrence characteristics of the target-dialect elements in the signal and noise patterns can now be summarized as follows:

(9) a. Elements the same as those in the source dialect

b. Elements different from those in the source dialect:

i. Elements not occurring in the source dialect

ii. Elements occurring elsewhere in the source dialect

Again, we assume that signal enhances intelligibility and noise reduces it. The occurrence characteristics can be used to fine-tune the value. Let us consider signal patterns first. If both dialects in question have the same elements for the items compared, then the intelligibility should be the highest. When the elements are different and the target-dialect elements also appear in other items of the source dialect, it is possible to confuse the items. But as signal such a pattern is a major one, and the large number of items involved could give a distinct impression that could more than offset confusion. For example, the lateral of Jinan corresponding to the voiced retroflex fricative in Beijing with 18 items as shown in (6) is somewhat salient even though Beijing has the lateral occurring in other words. When a signal pattern of correspondence between an element of the source dialect and a different element of the target dialect which does not occur in the source dialect, the potential confusion is not as serious as when the target-dialect element also occurs elsewhere in the source dialect. For example the Beijing 55 tone corresponding to Jinan 213 tone in a large number of words can give Beijing speakers a distinct impression and therefore can allow for a consistent interpretation of tone 213 as 55. Thus the relationship for signal patterns in terms of the amount of communication enhancement of their corresponding elements can be given as follows:

(10) Same > Different and not occurring in the source dialect > Different and occurring elsewhere in the source dialect

Noise patterns are intelligibility reducers since they involve a small number of individual items. One may think of these patterns as idiosyncrasies that require extra efforts of attention to individual items. To what extent they reduce intelligibility is also dependent on the occurrence characteristics of their elements. A noise pattern which has different corresponding elements in the dialects and whose element in the target dialect also occurs in other non-cognate items of the source dialect may cause much confusion. In my view, that is the worst case for communication. When a noise pattern has the same element in both dialects, then the level of confusion is the least. Since noise reduces intelligibility, the noise pattern with the same corresponding element should be assigned the smallest negative value. Therefore the relationship for signal patterns as given in (10) holds for noise patterns. The only difference is that noise patterns take on negative values. If we state the relationship of the corresponding elements according to severity of interference, then the direction of the greater signs in (10) can be reversed as given in (11) to show an ascending order of confusion:

(11) Same < Different and not occurring in the source dialect < Different and occurring elsewhere in the source dialect

Now that we have the relationship, we will propose the weight scale. If we use a unitary value of 1 for each item, then the following assignments of weight can be made:

(12)

			Signal	Noise
For each item in a pattern, the target-dialect				
a.	element is the same as that of the source dialect:		1.00	-0.25
b.	element is different from that of the source dialect			
	i.	and does not occur in the source dialect:	0.50	-0.50
	ii.	and occurs elsewhere in the source dialect:	0.25	-1.00

First, since signal enhances intelligibility, its values are positive, and since noise reduces intelligibility, its values are negative. Second, the highest absolute value is 1, and the absolute values of the other two occurrence characteristics are each reduced by half of its precedence.

This weight scale provides a straightforward numerical interpretation of the occurrence characteristics of elements in correspondence patterns. However, a series of questions of theoretical import can be raised. For example, earlier in showing the Beijing-Jinan correspondence of phonological elements, we assumed that the pattern of /n/ corresponding to /l/ had the same weight value as the pattern of /n/ corresponding to the zero initial. How do we know if this assumption is valid or not? One way to resolve this issue is to study what can be called perceptual distance of phonological segments. We will be examining the theoretical bases and the implications of our analysis of intelligibility in the near future.

The examples of correspondence patterns shown earlier are of phonological nature. However, it is hoped that the proposed procedures and the weight scale for deriving language intelligibility can be used to quantify various types of linguistic components such as phonology, morphology, syntax, etc. Each component will have its own items and elements to deal with. We have not worked on all these areas, but an attempt to quantify Chinese dialect mutual intelligibility in terms of phonological elements in cognate words has produced interesting results. In the following we will recapitulate the work done in Cheng (1990, 1992) to illustrate the calculation of dialect mutual intelligibility.

4. Syllable-based Mutual Intelligibility

Generally speaking, Chinese words are coterminous with the syllable. To study Chinese dialect mutual intelligibility, the best starting point is the syllable-word. Words are shared as cognates by the dialects, and the elements of the syllable can be used to establish correspondence patterns. Because the entire syllable as a unit is too coarse to show the fine details of dialectal differences, we divide the syllable into the five traditional elements of initial, medial, vowel, ending, and tone for measurement. If we give a syllable a value of 1, then each of these elements will have the value of 0.20. This assumes that the initial, medial, vowel, ending, and tone have the same weight. It may turn out that the vowel of the syllable is weightier in determining perception. But lacking such information we have to use an equal-weight valuation for now. According to the general weight scale proposed in (12) the weight scale for each of these phonological elements can be determined as follows:

(13)

			Signal	Noise
For each item in a pattern, the target-dialect's phonological				
a.	element is the same as that of the source dialect:		0.20	-0.05
b.	element is different from that of the source dialect			
	i.	and does not occur in the source dialect:	0.10	-0.10
	ii.	and occurs elsewhere in the source dialect:	0.05	-0.20

Each value is scaled down to one-fifth from that proposed in (12) to reflect the fact that five elements make up one syllable-word.

We extracted the five elements from the computerized version of the *Hanyu Fangyin Zihui* (Beijing University 1962, 1989) and formed correspondence patterns for all the pairs of the 17 dialects, each once as the source dialect and once as the target dialect, thus making 272 pairs. Below we will use the Beijing-Jinan pair with Beijing as the source dialect to show how the unidirectional intelligibility is calculated. The correspondence patterns for the initials, medials, vowels, endings, and tones are listed with the number of items (frequency) and mean in Table 1. As the mean determines whether a pattern is signal or noise, the weight according to (13) is also given. The frequency multiplied by the weight is the value of the pattern. And as we continue to list the patterns the values are summed and shown. For each pattern an example in Chinese character is given as evidence of the correspondence. In the Table the initials are ordered in terms of the alphabetic sequence of the letters representing the IPA. The initials are followed by the medials /i/, /u/, and /y/ (high-front rounded). Then the vowel and tone elements follow. The arrangements of these elements in the Table have no particular significance for the calculation process. Only the final sum is used to derive the unidirectional intelligibility.

To understand how the values are calculated, let us look at the first two lines of the Table. These two lines show the Beijing-Jinan correspondence patterns with respect to the zero initial in Beijing. They show that the Beijing zero initial corresponds to the Jinan zero initial with 290 words and to the Jinan velar nasal with 30 words. The mean of these two patterns is 160.00. Since 290 is greater than 160, the first pattern is considered signal. Since the corresponding elements in the first pattern are the same zero initial, the weight according to (13) is .20. The value of 58.00 is derived from 290 multiplied by the weight of .20. The sum at this point is 58.00. The frequency of the second pattern of the zero initial corresponding to the velar nasal is smaller than the mean. The pattern is therefore considered noise. As the velar nasal initial does not occur in Beijing, the weight is given as -.10. The frequency (30) is multiplied by the weight to yield the value of -3.00. The sum at this point is 55.00 (58.00 - 3.00).

At the end of Table 1 we obtain the sum of 2,004.25. There are 2,763 syllable-words considered. And the unidirectional intelligibility with Beijing as the source dialect is the sum divided by the number of syllable-words tabulated, i.e. 2004.25 / 2763 = 0.725. We can tabulate the correspondence patterns for Jinan and Beijing with Jinan as the source dialect in the same fashion. Indeed, we calculated all the pairs of the 17 dialects. The unidirectional intelligibility with Jinan as the source dialect is 0.713. We then calculate the mutual intelligibility by taking the mean of the unidirectional intelligibility values. Thus the Beijing-Jinan mutual intelligibility is (0.725 + 0.713) / 2 = 0.719.

All the 272 (17 x 16) pairs of the 17 dialects have been so computed and the values are given in Table 2. Each pair of the dialects in Table 2 has three numbers. The first one is the unidirectional intelligibility of the pair with the dialect given in the column as the source dialect. The second number is the unidirectional intelligibility of the pair with the dialect given in the row as the source dialect. The third number is the mean of these two numbers and is the mutual intelligibility of the pair.

By definition, the values of intelligibility can vary from -1 to 1. In these Chinese dialects, the unidirectional intelligibility values so calculated vary from the lowest .341 for the Guangzhou-Shuangfeng pair and the Wenzhou-Xiamen pair to the highest .799 for the Chengdu-Hankou pair. We calculate the mutual intelligibility by taking the mean of the two unidirectional intelligibility values of a pair of the dialects. We hope that this mean would not obliterate large differences between the two unidirectional intelligibility values of a pair. For example, as shown in Table 2 the Beijing-Jinan value is .725 and the Jinan-Beijing value is .713; the difference is .012. Indeed, as we examine all the pairs of the dialects the differences between the two unidirectional intelligibility values are all very small, ranging from 0 for the pair of Shuangfeng and Chengdu to .114 for the pair of Xiamen and Wenzhou. Empirically, the mean does not give a number drastically different from those of unidirectional intelligibility.

The values show different DEGREES of mutual intelligibility. However, one might wish to know if the value of .500 would mean exactly that hearers can understand 50% of what is said. A similar question would be at what point of the scale speakers of a pair of languages cannot communicate with one another. These are empirical questions and require empirical studies to find the answers. In actual speech communication, the linguistic background, experience, ability, and knowledge of the communication participants all contribute to mutual understanding. This is why I have proposed to make a distinction between systemic mutual intelligibility, which describes a pair of languages in terms of their systems and correspondence patterns, and participant mutual intelligibility, which is based on systemic mutual intelligibility and which takes into consideration personal experience and linguistic ability of individuals (Cheng 1990, 1992).

The intelligibility calculated in terms of the correspondence patterns of syllable-words between the pairs of the 17 Chinese dialects is an attempt to quantify systemic mutual intelligibility. The scope is limited, leaving out syntactic, semantic, discoursal, and other linguistic correspondence patterns. It is hoped that in the future as we know more about this field we will be able to incorporate more relevant elements for a fuller account of mutual intelligibility. However, in the past, studies in Chinese language standardization, dialect classification, dialect affinity, and historical evolution all had a sharp focus on the elements of the syllable-word. It is therefore appropriate to start our mutual intelligibility investigation with the syllable-word. Hopefully some meaningful comparisons can be made with these other types of studies.

Various uses of quantified mutual intelligibility are discussed or alluded to in Cheng (1990, 1992). In the interest of quantitative studies, here we will direct our attention to the use of the intelligibility indices to establish a dialect grouping. At the beginning of this writing we mentioned that we often relied on some impressionist view of mutual intelligibility to establish dialect subgrouping. Now that we have derived the intelligibility indices for the 17 dialects, we can follow some rigorous procedures to establish dialect classification.

There are many ways to determine numerical taxonomy (see Ma 1989 for discussion). Here I will follow what I have been doing in the past few years so that a comparison of dialect affinity viewed from different perspectives can be made meaningfully. The subgrouping method that I employ is cluster analysis using average linking. This method groups the closest pairs first. Then it links the next closest dialects. Eventually a classification tree is established. The classification of these 17 dialects is given in Figure 1. I will explain the process of linking here. The first step of the process involves ranking the mutual intelligibility of the dialect pairs in a descending order. To illustrate this process, we extract from Table 2 and list the first 10 closest pairs in (14). Please note that since we are looking at the mutual intelligibility and not unidirectional intelligibility values the order of dialect in each pair is immaterial.

(14)	1	.795	Hankou-Chengdu
	2	.768	Jinan-Xi'an
	3	.727	Beijing-Hankou

4	.726	Beijing-Chengdu
5	.719	Beijing-Jinan
6	.693	Xi'an-Chengdu
7	.685	Beijing-Xi'an
8	.676	Hankou-Changsha
9	.660	Chengdu-Changsha
10	.657	Jinan-Chengdu

The closest pair, Chengdu and Hankou, first form a group. In Figure 1 we see that these two dialects are grouped together and the lines are joined at .795 on the scale. We then group the next closest pair, Jinan and Xi'an. In Figure 1 we see that Jinan and Xi'an are linked at .768 on the scale. The next closest pair is Beijing and Hankou. But Hankou has already been linked with Chengdu. It is therefore necessary to link Beijing with the Chengdu-Hankou pair. The average linking method obtains the average of the sum of the Beijing-Hankou (.727) and Beijing-Chengdu (.726) and link Beijing with the pair of Hankou and Chengdu at the average point ((.727 + .726) / 2 = .726). Thus we see in Figure 1 Beijing joins Hankou and Chengdu at .726.

Since the fourth closest pair of Beijing and Chengdu has been treated, we next go to process the fifth pair given in (14). Here Beijing and Jinan are to be linked at .719. But Beijing has already been linked with Hankou and Chengdu, and Jinan has already been linked with Xi'an. It is necessary to link these five dialects together. The average linking point is the average of the values of these six pairs: Jinan-Beijing (.719), Jinan-Hankou (.588), Jinan-Chengdu (.657), Xi'an-Beijing (.685), Xi'an-Hankou (.635), Xi'an-Chengdu (.693). Thus in Figure 1 these dialects are linked at .662 ((.719 + .588 + .657 + .685 + .635 + .693) / 6 = .662). These paragraphs illustrate the use of average linking in cluster analysis. As we complete the linking of all the dialect pairs, we obtain the classification tree of Figure 1.

The grouping as given in Figure 1 shows a remarkable similarity to what we know about the genetic relationships of these Chinese dialects. Suzhou appears at the north-south dividing point. Above it the dialects are mostly Mandarin except that Changsha is usually considered a separate Xiang dialect. The more diverse southern dialects come below Suzhou and are mostly less mutually intelligible. Moutain et al (1992:320) using a "neighbor-joining tree" linking method to group similar dialects according to lexical and phonological correlations also conclude that "Suzhou is not much more similar to the southern localities than it is to the northern ones." It seems that our general impressionist understanding of dialect mutual intelligibility is very well captured in this numerical taxonomy.

It is also interesting to compare this mutual intelligibility classification with the grouping established on the basis of genetic information. In Cheng (1986, 1988, 1991) the same *Hanyu Fangyin Zihui* (Beijing University 1962) syllable-words were tabulated for occurrences of the initials, finals, and tones according to historical relationships. The calculated historical correlation coefficients were then analyzed and linked to establish a classification. This genetic classification is reproduced in Figure 2. In this figure we see that Taiyuan stands out alone. This is due to the fact that in Taiyuan the Middle Chinese Even tone did not split into two tones as it did in all other dialects. Otherwise, the genetic classification is quite similar to that based on mutual intelligibility as given in Figure 1.

5. Concluding Remarks

The fact that the results of this quantitative study of mutual intelligibility match well our general impression of Chinese dialect mutual intelligibility might engender the feeling that the methodology is trivial. In my view, it is significant that the methodology provides a rigorous procedure for calculating mutual intelligibility. It gives a measurement that is verifiable and that is not based on the investigator's subjective judgments. Moreover, the numerical indices resulted from this calculation give a more precise description of the degrees of dialect relationships. As we said earlier, one of the goals of scientific investigations is to achieve the objective of expressing things in terms of verifiable measurements. It is my hope that this study has moved linguistic inquiries closer to that goal.

On the other hand, there are many areas that I have left untouched. I have proposed a measurement of mutual intelligibility that takes into consideration the patterns of dialectal correspondence and the weights of signal and noise in communication. The Chinese syllable-words conveniently provide cognates as the basis for determining correspondence patterns of the initials, medials, vowels, endings, and tones. The calculation of mutual intelligibility then seems straightforward and reasonable. It is not immediately clear how to apply the procedures that we have presented for syllable-words to other linguistic elements such as syntax, semantics, discourse, and pragmatics. A great deal of work on quantification of mutual intelligibility remains to be done.

We mentioned earlier that Voegelin and Harris (1951), Hickerson, Turner, and Hickerson (1952), and Pierce (1952) asked their subjects to listen to recorded passages and counted the percentage of correct scores as the degree of mutual intelligibility. I know of little work done on mutual intelligibility during the 1960s. In the middle 1970s Voiers (1977) presented a diagnostic evaluation of speech intelligibility. In recent years, as evaluation of computer synthesized speech was needed for technological improvements, speech intelligibility tests were designed or carried out. For example, Mack, Tierney, and Boyle (1990) used Diagnostic Rhyme Test, Meaningful Sentence Test, and Semantically Anomalous

Sentences Test to compare the intelligibility of natural and computer-generated speech presented to native English and German speakers. All these studies cited here and those appear in Hawley (1977) are experimental in nature and involve the use of subjects. And speech intelligibility was, by and large, the percentage of correct scores made by the human subjects. While these tests are important for evaluating human understanding of speech, the results vary from subject to subject and therefore do not account for the mutual intelligibility of languages as systems. As I stated earlier, the main interest of this writing is in the mutual intelligibility of languages at the systems level. I call this intelligibility systemic mutual intelligibility. The intelligibility calculated on the basis of the tests with speakers can be called subjective or participant mutual intelligibility. Since a speaker's use of a language is basically defined by the language as a system, I feel that systemic mutual intelligibility is the basis for establishing a fuller account of participant mutual intelligibility. However, a meaningful proposal for integrating subjective experience and ability into systemic mutual intelligibility to account for personal variation has yet to be made.

As we study further the theoretical issues mentioned or alluded to here in this writing, we hope to extend linguistics beyond its current boundaries At this moment, we are not yet entirely ready to answer laymen's questions about mutual intelligibility. There are many language matters that we do not yet understand. But that is the fun of doing linguistics.

		frequency	mean	weight	value	sum	example
Initials							
	:	290	160.0	0.20	58.00	58.00	五
	: ŋ	30	160.0	-0.10	-3.00	55.00	哀
ɕ	:	2	83.5	-0.20	-0.40	54.60	淆
ɕ	: ɕ	165	83.5	0.20	33.00	87.60	先
f	: f	95	48.5	0.20	19.00	106.60	夫
f	: p^h	2	48.5	-0.20	-0.40	106.20	埠
k	: k	126	64.0	0.20	25.20	131.40	鬼
k	: tɕ	2	64.0	-0.20	-0.40	131.00	更
k^h	: k^h	73	73.0	0.20	14.60	145.60	快
l	: l	171	171.0	0.20	34.20	179.80	拉
m	: m	97	97.0	0.20	19.40	199.20	麻
n	:	3	10.6	-0.20	-0.60	198.60	[illegible]
n	: l	1	10.6	-0.20	-0.20	198.40	嫩
n	: n	27	10.6	0.20	5.40	203.80	纳
n	: ɲ	21	10.6	0.10	2.10	205.90	泥
n	: s	1	10.6	-0.20	-0.20	205.70	尿
p	: p	131	66.5	0.20	26.20	231.90	比
p	: p^h	2	66.5	-0.20	-0.40	231.50	堡
p^h	: p	1	44.0	-0.20	-0.20	231.30	堡
p^h	: p^h	87	44.0	0.20	17.40	248.70	皮
s	: ɕ	5	19.5	-0.20	-1.00	247.70	俗
s	: ɲ	1	19.5	-0.10	-0.10	247.60	尿
s	: s	65	19.5	0.20	13.00	260.60	素
s	: ʂ	7	19.5	-0.20	-1.40	259.20	瑟
ʂ	: ʂ	146	73.5	0.20	29.20	288.40	社
s	: $tʂ^h$	1	73.5	-0.20	-0.20	288.20	殊
t	: t	139	139.0	0.20	27.80	316.00	大
t^h	: t^h	118	118.0	0.20	23.60	339.60	他
tɕ	: tɕ	225	113.5	0.20	45.00	384.60	己
tɕ	: $tɕ^h$	2	113.5	-0.20	-0.40	384.20	[illegible]

Table 1. Computation of Beijing-Jinan Intelligibility

tɕ^h	: k^h	2	55.0	-0.20	-0.40	383.80	般
tɕ^h	: tɕ^h	108	55.0	0.20	21.60	405.40	七
ts	: tɕ	1	25.0	-0.20	-0.20	405.20	足
ts	: ts	70	25.0	0.20	14.00	419.20	組
ts	: tʂ	4	25.0	-0.20	-0.80	418.40	擇
ts^h	: s	1	15.7	-0.20	-0.20	418.20	賜
ts^h	: ts^h	58	15.7	0.20	11.60	429.80	粗
ts^h	: tʂ	1	15.7	-0.20	-0.20	429.60	側
ts^h	: tʂ^h	3	15.7	-0.20	-0.60	429.00	冊
tʂ	: tɕ	1	92.0	-0.20	-0.20	428.80	鑄
tʂ	: tʂ	183	92.0	0.20	36.60	465.40	主
tʂ^h	: tʂ	1	63.0	-0.20	-0.20	465.20	觸
tʂ^h	: tʂ^h	125	63.0	0.20	25.00	490.20	出
x	: k^h	1	62.0	-0.20	-0.20	490.00	潰
x	: x	123	62.0	0.20	24.60	514.60	胡
ʐ	:	2	15.0	-0.20	-0.40	514.20	潤
ʐ	: l	18	15.0	0.05	0.90	515.10	如
ʐ	: ʐ	25	15.0	0.20	5.00	520.10	人

Medials

	:	1775	469.0	0.20	355.00	875.10	他
	: i	62	469.0	-0.20	-12.40	862.70	因
	: u	13	469.0	-0.20	-2.60	860.10	嫩
	: y	26	469.0	-0.20	-5.20	854.90	韻
i	:	2	117.5	-0.20	-0.40	854.50	般
i	: i	461	117.5	0.20	92.20	946.70	限
i	: u	1	117.5	-0.20	-0.20	946.50	尿
i	: y	6	117.5	-0.20	-1.20	945.30	腳
u	:	2	89.5	-0.20	-0.40	944.90	它
u	: i	1	89.5	-0.20	-0.20	944.70	尿
u	: u	351	89.5	0.20	70.20	1014.90	回
u	: y	4	89.5	-0.20	-0.80	1014.10	損

Table 1. Continued

y	: i	1	19.6	-0.20	-0.20	1013.90	緣
y	: u	1	19.6	-0.20	-0.20	1013.70	略
y	: y	57	19.6	0.20	11.40	1025.10	全

Vocalic elements

a	: a	326	360.5	-0.05	-16.30	1008.80	打
a	: ã	395	360.5	0.10	39.50	1048.30	站
ai	: ei	14	52.5	-0.20	-2.80	1045.50	百
ai	: ɛ	91	52.5	0.10	9.10	1054.60	拜
au	: e	6	47.6	-0.20	-1.20	1053.40	腳
au	: ei	1	47.6	-0.20	-0.20	1053.20	尿
au	: ə	7	47.6	-0.20	-1.40	1051.80	殼
au	: ɔ	223	47.6	0.10	22.30	1074.10	要
au	: u	1	47.6	-0.20	-0.20	1073.90	堡
e	: æ	12	28.0	-0.10	-1.20	1072.70	介
e	: e	71	28.0	0.20	14.20	1086.90	借
e	: ə	1	28.0	-0.20	-0.20	1086.70	略
ei	: ei	139	70.0	0.20	27.80	1114.50	非
ei	: ɔ	1	70.0	-0.10	-0.10	1114.40	尿
ə	: ẽ	118	73.3	0.10	11.80	1126.20	神
ə	: ə	100	73.3	0.20	20.00	1146.20	省
ə	: i	2	73.3	-0.20	-0.40	1145.80	更
ɚ	: ɚ	4	4.0	0.20	0.80	1146.60	二
i	: ẽ	60	92.5	-0.10	-6.00	1140.60	心
i	: ei	5	92.5	-0.20	-1.00	1139.60	披
i	: i	304	92.5	0.20	60.80	1200.40	立
i	: y	1	92.5	-0.20	-0.20	1200.20	傾
ɪ	: ɪ	35	35.0	0.20	7.00	1207.20	字
ɩ	: ɩ	81	81.0	0.20	16.20	1223.40	知
o	: a	1	34.3	-0.20	-0.20	1223.20	它
o	: ei	6	34.3	-0.20	-1.20	1222.00	伯
o	: ə	96	34.3	0.05	4.80	1226.80	博

Table 1. Continued

ou	: ou	136	47.0	0.20	27.20	1254.00	豆
ou	: ɔ	1	47.0	-0.10	-0.10	1253.90	否
ou	: u	4	47.0	-0.20	-0.80	1253.10	某
ɤ	: a	1	25.6	-0.20	-0.20	1252.90	蛇
ɤ	: ei	19	25.6	-0.20	-3.80	1249.10	責
ɤ	: ə	57	25.6	0.05	2.85	1251.95	舍
u	: ɔ	1	109.3	-0.10	-0.10	1251.85	堡
u	: u	322	109.3	0.20	64.40	1316.25	夫
u	: y	5	109.3	-0.20	-1.00	1315.25	俗
y	: ẽ	26	58.0	-0.10	-2.60	1312.65	韻
y	: y	90	58.0	0.20	18.00	1330.65	女

Endings

	:	1638	1638.0	0.200	327.60	1658.25	苦
n	:	597	597.0	0.050	29.85	1688.10	年
ŋ	: ŋ	528	528.0	0.200	105.60	1793.70	方

Tones

55	: 213	668	171.5	0.10	66.80	1860.50	家
55	: 42	9	171.5	-0.10	-0.90	1859.60	敷
55	: 55	5	171.5	-0.05	-0.25	1859.35	估
55	: 21	4	171.5	-0.10	-0.40	1858.95	晉
35	: 213	44	169.5	-0.10	-4.40	1854.55	伯
35	: 42	610	169.5	0.10	61.00	1915.55	河
35	: 55	13	169.5	-0.20	-2.60	1912.95	國
35	: 21	11	169.5	-0.10	-1.10	1911.85	如
214	: 213	34	118.2	-0.10	-3.40	1908.45	且
214	: 42	6	118.2	-0.10	-0.60	1907.85	努
214	: 55	422	118.2	0.05	21.10	1928.95	土
214	: 21	11	118.2	-0.10	-1.10	1927.85	左
51	: 213	58	231.5	-0.10	-5.80	1922.05	踏

Table 1. Continued

51	: 42	5	231.5	-0.10	-0.50	1921.55	或
51	: 55	12	231.5	-0.20	-2.40	1919.15	各
51	: 21	851	231.5	0.10	85.10	2004.25	布

value sum: 2004.25

total number of syllable-words: 2763

intelligibility: 2004.25 / 2763 = .725

Table 1. Continued

	Beijing A	JN B	XA C	TY D	HK E	CD F	YZ G	SZ H	WZ I	CS J	SF K	NC L	MX M	GZ N	XM O	CZ P
Jinan B	.725 .713 .719															
Xi'an C	.715 .656 .685	.771 .765 .768														
Taiyuan D	.609 .608 .608	.603 .612 .607	.612 .617 .614													
Hankou E	.727 .728 .727	.582 .594 .588	.627 .643 .635	.574 .590 .582												
Chengdu F	.722 .730 .726	.669 .646 .657	.697 .690 .693	.599 .633 .616	.791 .799 .795											
Yangzhou G	.558 .525 .541	.570 .567 .568	.650 .632 .641	.640 .622 .631	.609 .547 .578	.615 .605 .610										
Suzhou H	.510 .489 .499	.523 .500 .511	.546 .551 .548	.568 .549 .558	.587 .512 .549	.592 .498 .545	.612 .604 .608									
Wenzhou I	.407 .382 .394	.452 .404 .428	.464 .418 .441	.485 .400 .442	.467 .378 .422	.483 .399 .441	.436 .379 .407	.534 .492 .512								
Changsha J	.610 .608 .609	.572 .541 .556	.608 .579 .593	.520 .529 .524	.689 .663 .676	.688 .632 .660	.529 .530 .529	.534 .517 .525	.439 .514 .476							
Shuangfeng K	.499 .481 .490	.504 .458 .481	.506 .470 .488	.433 .421 .427	.522 .538 .530	.506 .506 .506	.453 .466 .459	.480 .523 .501	.414 .482 .448	.496 .503 .499						
Nanchang L	.577 .587 .582	.499 .497 .498	.536 .530 .533	.568 .560 .564	.583 .622 .602	.614 .622 .618	.546 .541 .543	.519 .561 .540	.376 .468 .422	.524 .563 .543	.494 .508 .501					
Meixian M	.504 .553 .528	.438 .492 .465	.465 .516 .490	.535 .557 .546	.549 .576 .562	.565 .580 .572	.483 .522 .502	.480 .572 .526	.418 .485 .451	.516 .532 .524	.411 .461 .436	.658 .655 .656				
Guangzhou N	.487 .464 .475	.480 .429 .454	.479 .431 .455	.455 .437 .446	.477 .463 .470	.458 .450 .454	.481 .454 .467	.484 .483 .483	.469 .473 .471	.454 .412 .433	.401 .341 .371	.522 .469 .495	.567 .528 .547			
Xiamen O	.457 .503 .480	.421 .458 .439	.453 .490 .471	.468 .476 .472	.486 .529 .507	.449 .506 .477	.452 .466 .459	.461 .525 .493	.341 .455 .398	.388 .448 .418	.406 .442 .424	.489 .537 .513	.511 .535 .523	.434 .515 .474		
Chaozhou P	.413 .473 .443	.417 .414 .415	.465 .465 .465	.517 .516 .516	.444 .492 .468	.463 .536 .499	.463 .487 .475	.439 .499 .469	.402 .489 .445	.412 .479 .445	.350 .356 .353	.477 .514 .495	.491 .504 .497	.396 .474 .435	.498 .510 .504	
Fuzhou Q	.490 .536 .513	.473 .451 .462	.487 .476 .481	.544 .539 .541	.483 .481 .482	.505 .524 .514	.506 .486 .496	.457 .511 .484	.405 .499 .452	.443 .492 .467	.386 .419 .402	.538 .547 .542	.557 .540 .548	.435 .503 .469	.534 .498 .516	.555 .545 .550

Table 2. Dialect Intelligibility

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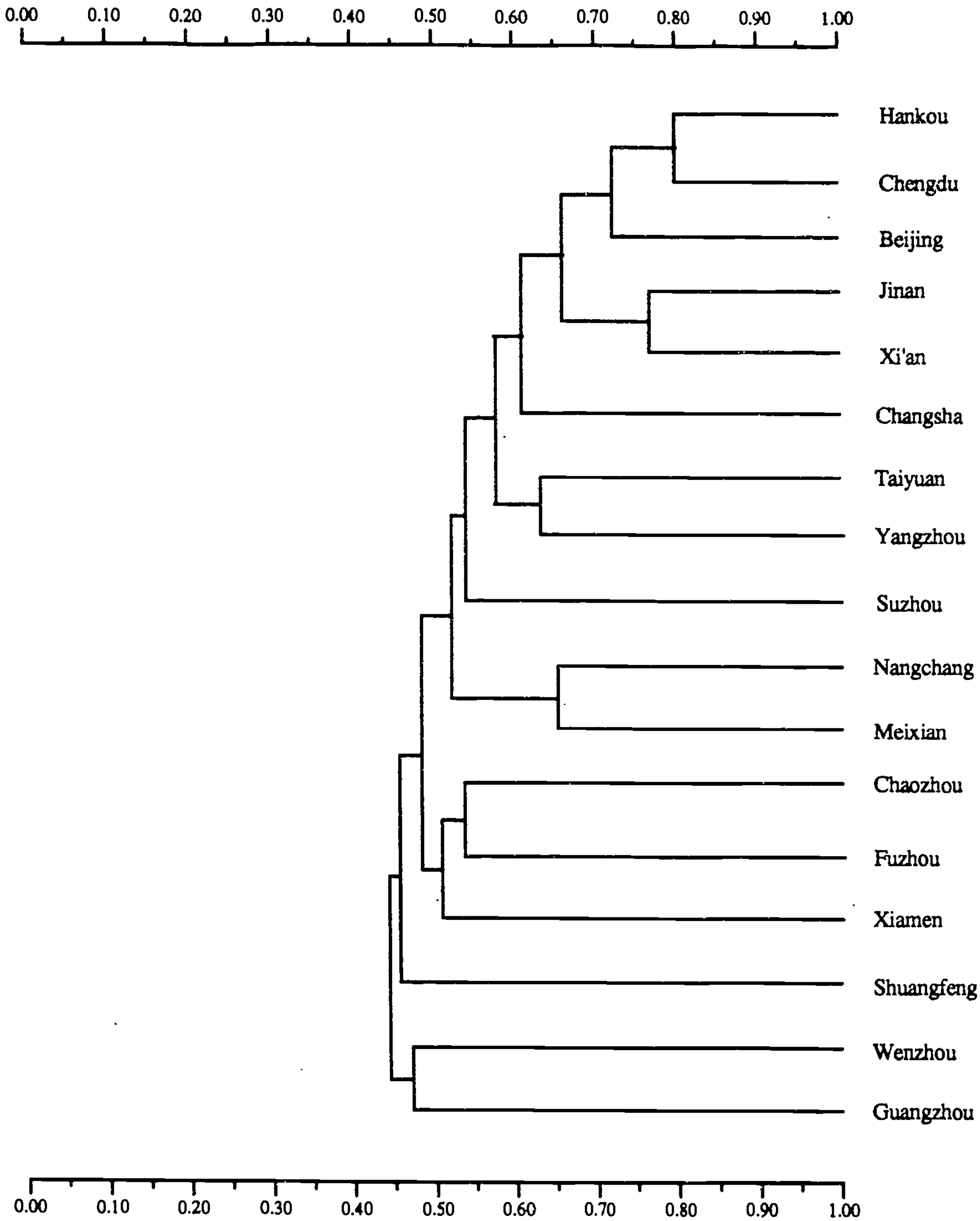

Figure 1. Dialect Affinity Based on Mutual Intelligibility

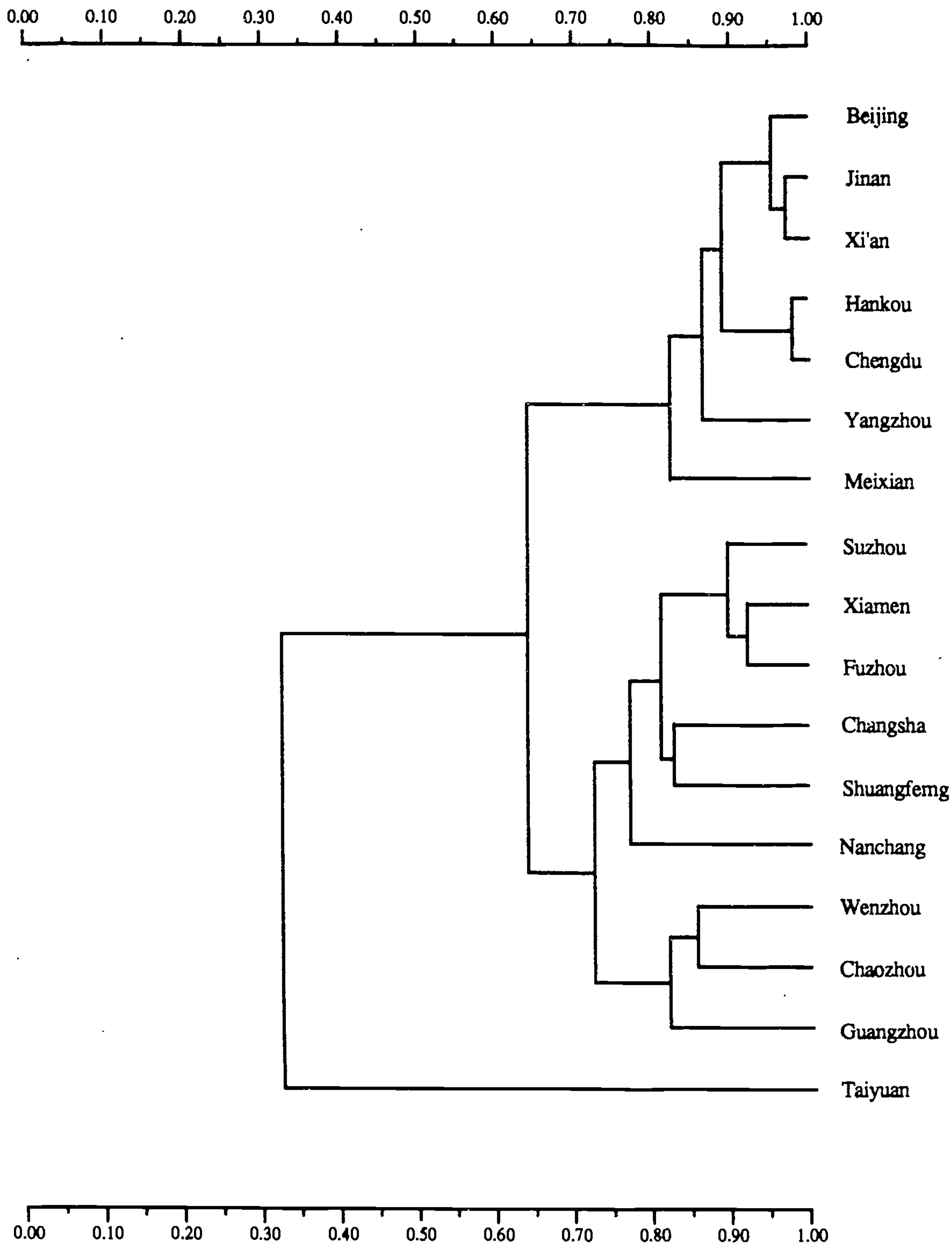

Figure 2. Dialect Affinity Based on Genetic Relations of Initials, Finals, and Tones

REFERENCES

Beijing University. 1962. *Hanyu Fangyin Zihui*. Beijing: Wenzi Gaige Chubanshe.

_____. 1989. *Hanyu Fangyin Zihui*. Second Edition. Beijing: Wenzi Gaige Chubanshe.

Cheng, Chin-Chuan. 1982. A quantification of Chinese dialect affinity. *Studies in the Linguistic Sciences* 12:1.29-47.

_____. 1986. *Quantifying Affinity Among Chinese Dialects*. Language Learning Laboratory Technical Report LLL-T-10-86, University of Illinois, Urbana, Illinois.

_____. 1987. A quantification of Chinese dialect affinity. In Chinese Language Society of Hong Kong (ed.) *Wang Li Memorial Volumes English Volume* 73-100. Hong Kong: Joint Publishing Co.

_____. 1988. Hanyu fangyan qinshu guanxi de jiliang yanjiu (Quantitative studies of Chinese dialect affinity). *Zhongguo Yuwen* 203.87-102.

_____. 1990. Syllable-based dialect classification and mutual intelligibility. Paper presented at the First International Symposium on Chinese Languages and Linguistics, Taipei, Taiwan.

_____. 1991. Quantifying affinity among Chinese dialects. In William S-Y. Wang (ed.) *Languages and Dialects of China* 77-112. *Journal of Chinese Linguistics* Monograph Series 3.

_____. 1992. Syllable-based dialect classification and mutual intelligibility. *Chinese Languages and Linguistics 1 Chinese Dialects* 145-177, Symposium Series Number 2. Taipei, Taiwan: Institute of History and Philology, Academia Sinica.

Hawley, Mones E. (ed.) 1977. *Speech Intelligibility and Speaker Recognition*. Stoudsburg, Pennsylvania: Dowden, Hutchinson & Ross.

Hickerson, Harold; Glen D. Turner; and Nancy P. Hickerson. 1952. Testing procedures for estimating transfer of information among Iroquois dialects and languages. IJAL 18.1-8.

kroeber, A. L., and C. D. Chretien. 1937. Quantitative classification of Indo-European Languages. *Language* 13.83-103.

Lu, Zhiji. 1986. Cluster analysis of associations among dialects in Fujian Province. *Yuyan Yanjiu* 2.9-16.

_____. 1991. *A Quantitative Model in Dialect Subgrouping: The Case of Modern Wu Dialects*. Ph.D. Dissertation, University of Illinois, Urbana, Illinois.

Lu, Zhiji, and Chin-Chuan Cheng. 1985. Chinese dialect affinity based on syllable initials. *Studies in the Linguistic Sciences* 15:2.127-148.

Ma, Xiwen. 1989. Bijiao fangyanxue zhong de jiliang fangfa (Quantitative methods in comparative dialectology). *Zhongguo Yuwen* 212.348-360.

Mack, Molly; Joseph Tierney; and Mary E. T. Boyle. 1990. The intelligibility of natural and LPC-vocoded words and sentences presented to native and non-native speakers of English. MIT Lincoln Laboratory Technical Report 869.

Mountain, Joanna L.; William S-Y. Wang; Du Ruofu; Yuan Yida; L. Luca Cavalli-Sforza. 1992. Congruence of genetic and linguistic evolution in China. *Journal of Chinese Linguistics* 20.315-331.

Ogura, Mieko. 1990. *Dynamic Dialectology: A Study of Language in Time and Space.* Tokyo: Kenkyusha.

Pierce, Joe E. 1952. Dialect distance testing in Algonquian. IJAL 18.208-218.

Reed, David W., and John L. Spicer. 1952. Correlation methods of comparing idiolects in a transition area. *Language* 28.348-359.

Tu, Wen-Chiu, and Chin-Chuan Cheng. 1991. A Linguistic classification of Rukai Formosan. Paper presented at the Sixth International Conference on Austronesian Linguistics, Honolulu, Hawaii. May 20-24.

Voegelin, Carl F., and Zellig S. Harris. 1951. Methods for determining intelligibility among dialects of natural languages. *Proceedings of the American Philosophical Society* 95.322-329.

Voiers, William D. 1977. Diagnostic evaluation of speech intelligibility. In Mones E. Hawley (ed.). *Speech Intelligibility and Speaker Recognition* 374-387. Stroudsburg, Pennsylvania: Dowden, Hutchinson & Ross.

Wang, William S-Y. 1987. Representing language relationships. In Hoenigswald and Wiener (eds.) *Biological Metaphor and Cladistic Classification* 243-256. Philadelphia, Pennsylvania: University of Pennsylvania Press.

_____. (ed.) 1991. *Languages and Dialects of China. Journal of Chinese Linguistics* Monograph Series Number 3.

Wang, William S-Y., and Zhongwei Shen. 1992. Fangyan guanxi de jiliang biaoda (A quantitative description of the relationship among Chinese dialects). *Zhongguo Yuwen* 227.81-92.

Wang, Yude. 1960. Chugokugo dai hogen no bunretsu nendai no gengo nendai gakuteki shitan (Lexicostatistic estimation of time depths of five major Chinese dialects). *Gengo Kenkyu* 38.33-105.

Yang, Dingfu. Ms. Jisuanji jiliang yanjiu Hanyu fangyan fenqu de tansuo (on quantitative Chinese dialect grouping).