

A New Method of Tonal Determination for Chinese Dialects

Yan Li

School of Foreign Languages,
Shaanxi Normal University,
Xi'an, China
e-mail: 2373515155@qq.com

Zhiyi Wu

Department of Psychology,
Carnegie Mellon University,
Pittsburgh, USA
e-mail: wuzhiyi.jenny@outlook.com

Abstract—Values of the basic tones are the key to do research on dialects in China. The traditional method of determining tones by ear and the more popular method used in experimental phonetics are either inaccurate to some degree or difficult to learn. The method provided and discussed in this paper is simple and reliable, requiring the use of only Praat and fundamental frequency value. More examples are given to prove this method's effectiveness.

Keywords—tonal determination; fundamental frequency value; Chinese dialects

I. INTRODUCTION

Tonal languages like Mandarin “generally use tones to represent phone level distinctions” [1]. Other than the official language called mandarin, there are many derivational languages distributed around China which are labeled as dialects. These dialects have high value in understanding the language development and diversity [2]. As a critical part of the dialects, basic tones need to be determined in order for further study. To understand the phonological features of a Chinese dialect, getting the basic tones is very fundamental and important.

II. TONAL DETERMINATION

The tonal studies have been more easily marked since Chao YR developed the five-degree system using tone numbers: pitch height with 5 being the highest and 1 being the lowest so it corresponds to the height and the movement. However, crucial as it is, the studies on Chinese dialects are still not advanced and unified enough to construct a more complete system. One reason lies in the difficulty of accurately determining the pitch heights of basic tones in each dialect. In the past few centuries, scholars relied mostly on their ears to distinguish among different tones in a diversity of dialects. Due to the differences among the auditory processing of individuals, the pitch heights of the basic tones in dialects tend to be numbered in more than one way. For example, sixteen different numbering systems have been developed for Lanzhou dialect by sixteen groups of scholars, who all determined the tones by ear [3]. Gladly, technology improvement has proved to compensate for the bad result caused by the subjectivity of human perception. As experimental linguistics advances, we now are able to normalize the “between-speaker (B-S) acoustical variance caused by physiological differences” among different individuals using different types of normalization methods

so that the invariant acoustic information can be extracted and specified [4]. Among all such methods, Chinese scholars favor D-value method, T-value method, and frequency domain quantile method more than the others [5][6]. Three studies analyzing Chongqing dialect with T-value method yielded the same basic tone values, which were different from those that were determined in the traditional way [7][8].

Although fundamental frequency method seemed promising and infallible for a while, undesirable results have arisen in many experiments regarding dialects. According to Feng Shi, “to investigate the tones, we should investigate the syllables with the same initial and final, and in the same place of the flow of speech.” [9] However, the flow of speech is difficult to control. Take the tonal determination of Ziyang dialect as example and apply simplified fundamental frequency graph to determine the tone. There are 4 tones in this dialect, we choose one character in each tone group, they are east “东”, door “门”, bitter “苦”, and ache “痛” to represent yinping, yangping, shangsheng and qusheng respectively, then get fundamental frequency value of each character through Praat (see Figure 1, 2, 3, 4). East “东” has a rising tone, fundamental frequency is between 139.8 and 197.1 Hz, door “门” has a falling tone, fundamental frequency is between 178.1 and 88.8 Hz, bitter “苦” has a rising tone, fundamental frequency is between 225 and 97.3 Hz, ache “痛” has a falling rising tone, fundamental frequency is from 133.8 to 128.4 to 206.2. From the fundamental frequency graph, we can get the detailed tones, here we still use 5-degree method (see Figure 5).

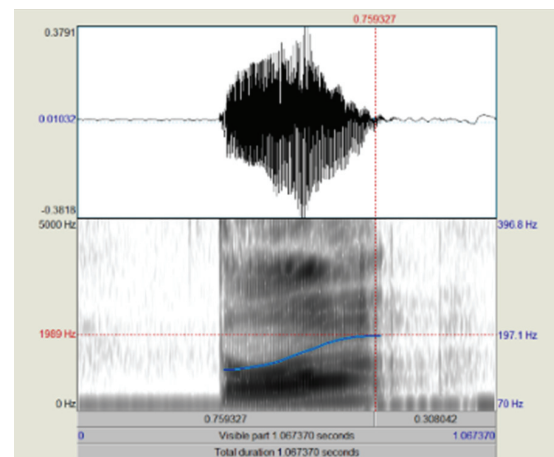


Figure 1: The Fundamental Frequency of East (“东”)

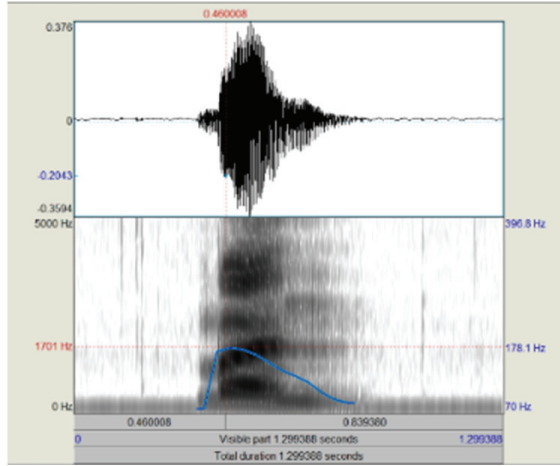


Figure 2: The Fundamental Frequency of *Door* (‘门’)

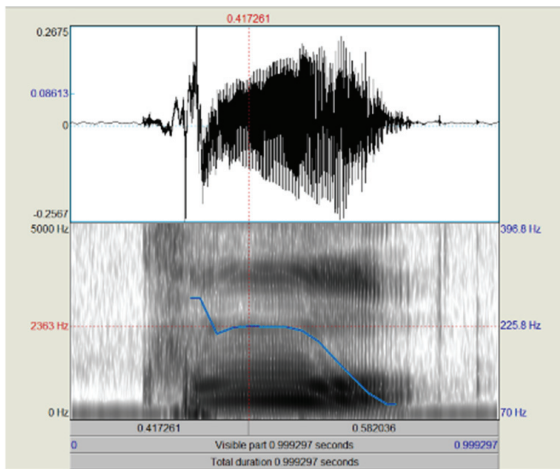


Figure 3: The Fundamental Frequency of *Bitter* (‘苦’)

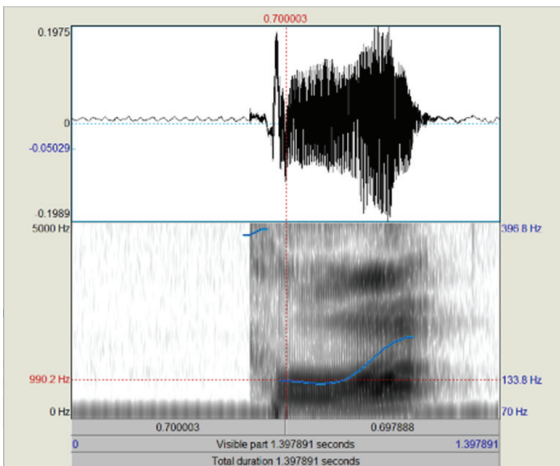


Figure 4: The Fundamental Frequency of *Ache* (‘东’)

Blue represents yinping east ‘东’, red represents yangping door ‘门’, grey shangsheng bitter ‘苦’, yellow qusheng ache ‘痛’. From Figure 5 we can see that yinping and qusheng starts from 2 and ends in 4 but qusheng has a little concave curve, we use 22 to express. Thus yinping is 24, yet qusheng is 224, yangping and shangsheng are both falling tones, yangping starts from 4, shangsheng from 5,

both end in 1, so yangping is 41, shangsheng is 51. According to the fundamental frequency graph of these four characters, the tone value should be: yinping 24, yangping 41, shangsheng 51, qusheng 224.

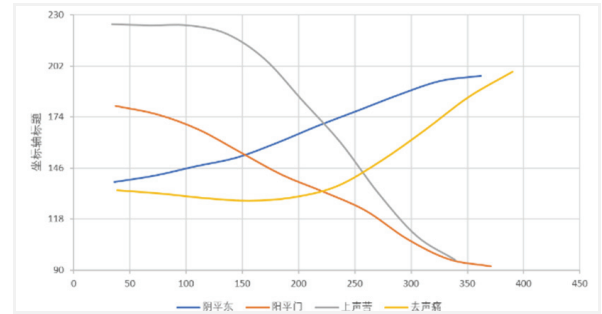


Figure 5: The Fundamental Frequency Curve Graph of ‘东’, ‘门’, ‘苦’, ‘痛’

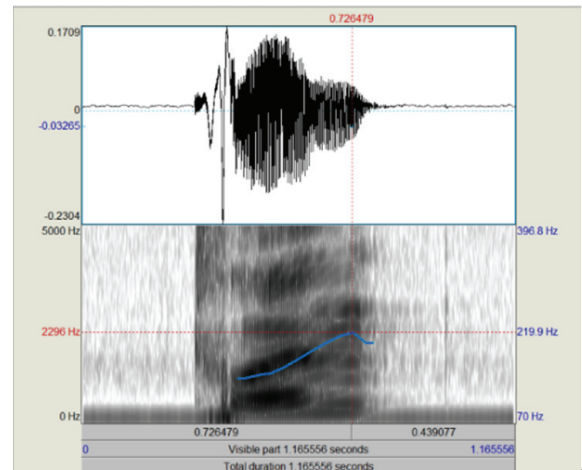


Figure 6: The Fundamental Frequency of *Spring* (‘春’)

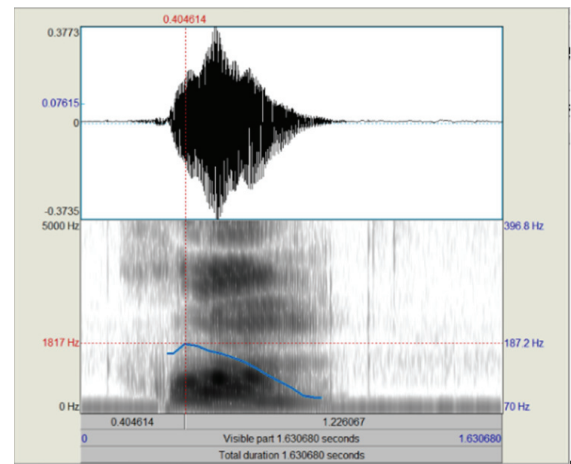


Figure 7: The Fundamental Frequency of *Red* (‘红’)

However, if we choose another group of characters, what will happen? Will they have the same tone as previous group? Here we choose spring 春, red 红, old 老, earth 地. Their values in Praat are (see Figure 6, 7, 8, 9): spring’s fundamental frequency is between 145 and 219.9 Hz, red 186.1 and 97.3 Hz, old 209.7 and 105.6 Hz, earth

131.5, 119.7 and 196.6 Hz. According to fundamental frequency graph (see Figure 10), their tones are yinping 25, yangping 41, shangsheng 51, qusheng 114 respectively. They are not the same as the previous group, especially yinping and qusheng.

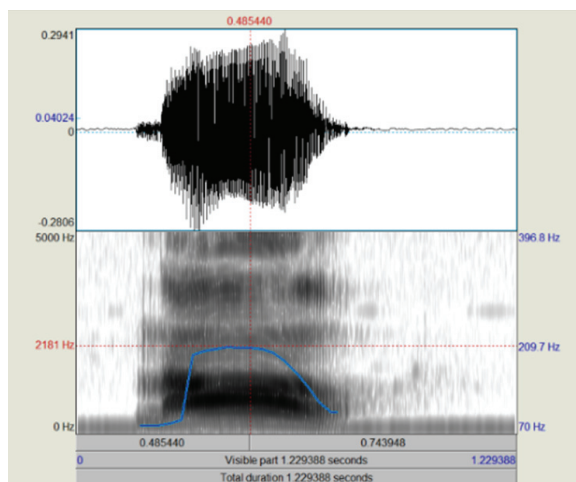


Figure 8: The Fundamental Frequency of *Old* (‘老’)

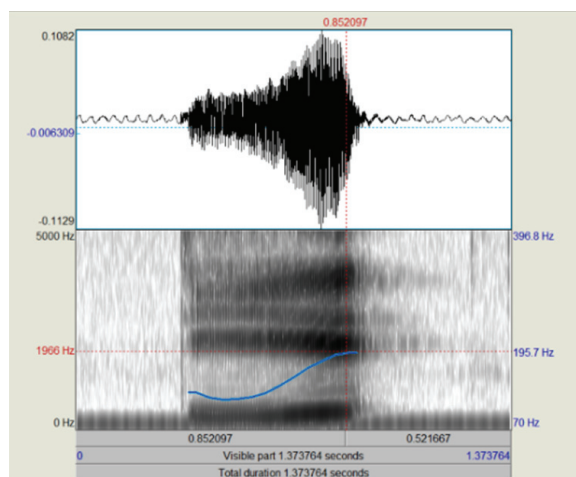


Figure 9: The Fundamental Frequency of *Old* (‘地’)

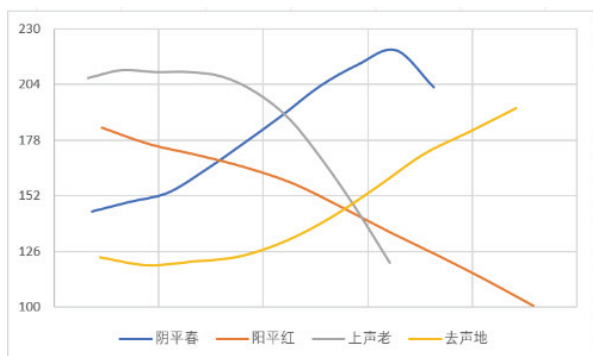


Figure 10: The Fundamental Frequency Curve Graph of ‘春’, ‘红’, ‘老’, ‘地’

Now we get more characters from each tone group, 7 characters from yinping group: should 该, east 东, light 灯,

wind 风, through 通, open 开, sky 天, 9 from yangping group: door 门, dragon 龙, oil 油, copper 铜, hundred 百, joint 节, worry 急, cry 哭, pat 拍, 9 from shangsheng group: understand 懂, ancient 古, ghost 鬼, nine 九, unite 统, bitter 苦, buy 买, five 五, have 有, 10 from qusheng group: sell 卖, road 路, hard 硬, chaos 乱, hole 洞, earth 地, meal 饭, tree 树, freeze 冻, odd 怪, then get the average value, according to average value we get the fundamental frequency curve graph (see Figure 11). From this figure the tone value should be 24, 41, 51, 224, quite different from the previous two (see Table 1, 1, 2, 3 represents three different results respectively).

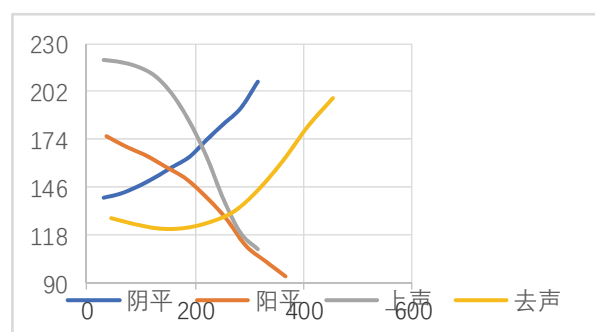


Figure 11: The Fundamental Frequency Curve Graph of Ziyang Dialect

Table 1: Different Tone Values from Different Groups of Characters

	yinping	yangping	shangsheng	qusheng
1	24	41	51	224
2	25	41	51	114
3	25	31	51	224

From the above discussion we can see that even if we use fundamental frequency graph, the tone value is not stable. The character example is the key point. When we investigate the tones of a character or a word, the informant couldn't possibly produce the same tone every time even if they belong to the same tone group, e.g., shangsheng group in Shuanghe town dialect in Ziyang County, the fundamental frequency of fire 火 is between 211-167 Hz, write 写 251-98 Hz, tile 瓦 201-184 Hz, tiger 虎 244-192 Hz. All these characters belong to shangsheng group, but their fundamental frequencies are quite different, the highest point of the beginning reaches 252 Hz, the lowest is 201, the ending part is from 192 Hz to 98 Hz. If we depend on the fundamental frequency graph, it's hard to get the same tone value. Now turn to another person's pronunciation, this time we take yangping in Huaping dialect in Ankang City as an example, eggplant 茄 171-120Hz, grandma 婆 153-93 Hz (in the middle there appears a creaky voice), tooth 牙 174-55 (also appears a creaky voice), except 除 163-125 Hz, fish 鱼 155-114 Hz, complete 齐 164-113 Hz, compensate 赔 179-119 Hz. They all belong to the same tone group, but their tones are not the same with the starting point from 179 Hz to 153 Hz and the ending point from 125 to 55. If we get about 10 characters

from each tone group and the average value from the fundamental frequency graph, there appears one problem, the duration of each word is not the same. Even if we have the average value, the duration time is hard to control.

The traditional method by ear is not reliable, and the phonetic experimental study on dialectal tones has more or less disadvantages and not credible. In addition, experimental phonetic method needs special training. Hence finding an objective, reliable, practical and convenient way to mark the tone is inevitable.

III. THE STEPS OF DETERMINING THE TONES

How to determine the tone exactly is an aporia for many scholars. Thus we try many ways to make sure that one way is more accurate and simpler than the others. The steps are as follows:

First, get the fundamental frequency of some representative characters, we can see the highest value and the lowest value clearly (it's better to abandon the characters which contain the highest value and the lowest value in order to avoid the fortuity and extremeness) through Praat software. Then the secondary highest value subtracts the secondary lowest value, we get the remainder. Since five degree system is always applied to mark the tone, the remainder is divided by 5, we get the average value. Add this average value to the secondary lowest tone, e.g., the secondary lowest tone is 95, the average value is 24, then the second number is 119, the third is 143, the fourth is 167, the fifth is 191, the sixth is 215. This time we take Huaping dialect as example.

First step: list the representative characters and fundamental frequency, 8 characters from each group, the more example characters, the better (because of the lack of space, we only get 8. Fundamental frequency unit: Hz (the number after the decimal point is deleted)) (see Appendix 1).

Second step: Find out the highest value and lowest value of fundamental frequency.

The highest value is 272, the lowest value is 100 (here we didn't delete the highest value and lowest value). Then the highest value subtracts the lowest value, we get the remainder 172. 172 divided by 5 is 34.4 (we delete the number after the decimal point and get 35). Then add 35 to the lowest value 100, we get 135, then add 35 to the previous number, we get 135, 170, 205, 240, 275 successively.

Third step: Draw a graph. Make a fundamental frequency graph for the 8 characters in yinping group. Divide the numbers from 100 to 272 by 5, we can see the tones of these 8 characters in Figure 12: low 低 24, open 开 22, should 该 23, book 书 22, beginning 初 34, pig 猪 23, boot 靴 23, song 歌 23. According to majority rule, yinping should be 23. There is a much simpler method, that is, we don't need to draw a graph, just see which area each character belongs to. We have six numbers: 100, 135, 170, 205, 240, 275, five areas: 100-135, 136-170, 171-205,

206-240, 241-275. So low “低” (167-219 Hz)'s starting point 167 is in area 2: 136-170, ending point 219 is in area 4: 206-240, thus the tone of low “低” is 24.

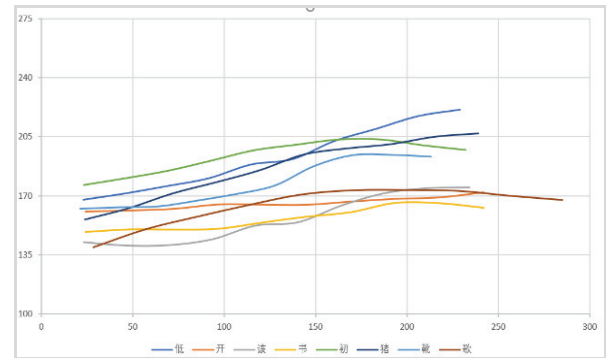


Figure 12: The Fundamental Frequency Graph for the 8 Characters of Yinping Group in Huaping Dialect

Fourth step: Determine the other tones in the same way. The tones of 8 characters in yangping group: compensate 赔 31, complete 齐 21, mud 泥 21, firewood 柴 21, hoe 锄 31, eggplant 茄 32, nose 鼻 21, late 迟 21. 21 is the majority, so yangping should be 21. The tones of 8 characters in shangsheng group: ghost 鬼 54, understand 懂 54, ancient 古 54, nine 九 54, bitter 苦 54, grass 草 43, buy 买 44, old 老 54, therefore shangsheng should be 54. The tones of 8 characters in qusheng group: move 动 224, crime 罪 224, odd 怪 212, ache 痛 224, inch 寸 225, near 近 113, hole 洞 224, tree 树 224, five characters' tone is 224, so qusheng is 224.

So far the four tones of Huaping dialect have been determined, yinping 23, yangping 21, shangsheng 54, qusheng 224. This method is feasible and objective and could avoid subjectivity. In the process of determining the tone, we should obey the following principles: (1) The more example characters, the better. We should get more example characters to make ensure the objectivity. In this paper we just choose 8 characters because of the limitation of space. (2) The majority rule. When a tone value appeared on more characters than the others, we choose this tone value. (3) Principle of balance. Each degree should appear, we can't lack any one of them. (4) Leave out the beginning and the end. We should delete characters with the highest fundamental frequency and the lowest one, in order to avoid extremity and fortuity.

IV. THE CASE STUDY

Let's return to Ziyang dialect. This dialect has been studied by Wang Li[10] and Zhou Zheng[11]. Wang Li[10] thinks Ziyang dialect has four tones: yinping 45, yangping 31, shangsheng 53, qusheng 214. Zhou Zheng[11] claims this dialect is close to Cheng Yu dialect, and has four tone categories, but the tone values are not the same as Wang Li's, they are 34, 21, 53, 213 respectively. The tone based on the above discussion about Ziyang dialect

according to a certain character or average value is also doubtful. At the moment we apply the above method to determine the tone value of Ziyang dialect. First choose about 10 characters, then get fundamental frequency value through Praat software (see Appendix 2).

From table 3, we can see that the highest value is 233 Hz, the lowest is 83, the remainder is 150. 150 divided by 5 is 30. According to five degree system, the numbers should be 83, 113, 143, 173, 203, 233. Using the simple method, determine the tones based on which area the fundamental frequency value belongs to. Five areas are: 83-113, 114-143, 144-173, 174-203, 204-233. Hence, the tones of these characters in yinping group are: east 东 24, wave 波 34, light 灯 25, ladder 梯 34, through 通 24, open 开 24, sky 天 35, spring 春 35. Since no tone is in the majority, we should choose more characters. Now we get five more characters in yinping group from the word list in sequence, they are: song 歌 35, boot 靴 34, should 该 23, west 西 34, dust 灰 34. In light of majority rule, yinping is 34. Let's turn to yangping: door 门 31, dragon 龙 31, cow 牛 31, oil 油 31, copper 铜 41, skin 皮 31, joint 节 41, late 迟 31. Most of tones are 31, therefore yangping is 31. Shangsheng: ghost 鬼 51, understand 懂 51, ancient 古 53, nine 九 51, bitter 苦 51, unite 统 51, buy 买 51, have 有 51. Most of tones are 51, so shangsheng is 51. Qusheng: move 动 225, crime 罪 325, odd 怪 224, ache 痛 225, back 后 225, near 近 225, four 四 325, half 半 114, qusheng should be 225. Till now we can determine the four tones of Ziyang dialect: yinping 34, yangping 31, shangsheng 51, qusheng 225.

Look at Zhenba dialect. Both Wang Li[10] and Huang Houju[12] regard it has four tone categories, yinping 45, yangping 31, shangsheng 54, qusheng 324. If we use the fundamental frequency graph, what's the tone value?

First, choose some characters from the word list. Here we choose 8 characters in each group (see Appendix 3).

The highest value in Zhenba dialect is 172Hz, the lowest is 68, the remainder is 103, 103 divided by 5 equals to 20.6, we get 21, then the numbers from the lowest one are as follows: 69, 90, 111, 132, 153, 174, five areas are 69-90, 91-111, 112-132, 133-153, 154-174 respectively. Let's look at the tone values of each character. Yin ping group: more 多 23, song 歌 34, wave 波 34, boot 靴 34, cock 鸡 35, open 开 35, district 区 45, spring 春 34, 34 is in the majority, thus accordingly, yinping should be 34, of course we can find more characters to validate. Yangping: eggplant 茄 32, except 除 41, tea 茶 21, grandma 婆 31, row 排 31, mud 泥 31, complete 齐 31, compensate 赔 31, hence yangping must be 31. Shangsheng: fire 火 53, tile 瓦 32, ancient 古 42, bitter 苦 43, five 五 43, tiger 虎 53, host 主 51, buy 买 21, we have the same numbers of tone 53 and tone 43, but for the purpose of balance, we had better choose 53. Consequently, shangsheng is 53. Qusheng: mill

磨 113, sit 坐 214, pass 过 14, thank 谢 113, anger 怒 224, do 做 224, saw 锯 225, half 半 224, here qusheng should be 224. Now we get the tone values of Zhenba dialect: yinping 34, yangping 31, shangsheng 53, qusheng 224.

By using this method, we can easily figure out each person's tone value and learn all nuances of tone and could avoid subjectivity.

V. CONCLUSION

This article discusses the determination of tones by means of fundamental frequency graphs and South Shaanxi dialects. The method by this way is not only simple and reliable, but also convenient and practical. Traditional method of determining tones by ear is not accurate enough, and the experimental phonetic method is much more difficult and not necessarily so exact. Yet comparing with these two methods, the method mentioned in this paper only needs Praat software and fundamental frequency value. At the same time, the value got by computer is much more objective than by brain. The tone determined by majority rule may avoid instability because one person's articulation could be high and low, long and short which interferes the precision of tone's determination. If the tone is determined by any one character, there will appear countless tone values. And for the complex tone, especial 2-contour tone, if we just rely on our ears, it's hard to decide the exact tone value, but by this method we can distinguish it explicitly.

REFERENCES

- [1] S. B. Davis and P. Mermelstein, "Comparison of parametric representation for monosyllabic word recognition in continuously spoken sentences," *IEEE Transactions on Acoustics, Speech and Signal Processing*, vol. 28, no. 4, pp. 357-366, 1980.
- [2] Z. Bao, "The Structure of Tone," Oxford University Press, 1999.
- [3] C. M. Y., "Tone Sandhi: patterns across Chinese dialects," Cambridge University Press, 2000.
- [4] Y. Li and Z. Xiaonong, "The Tonal Types of Mandarin in the Northwest," *Chinese Study*, 2015. [5] R. Phil. "Considerations in the normalization of the Fundamental Frequency of Linguistic Tone," *Speech Communication*, 1987.
- [6] Shi, Feng and Liang Rongrong, "Collections of Phonetics," Beijing Language Institute Press, 1994. [7] Lin, Tao and Wang Lijia, "The Course of Phonetics," Beijing University Press, 1999.
- [8] Liang, Lei and Meng Xiaolin, "Statistical Analysis of monosyllabic tone of Chongqing dialect," *Proceedings of the 9th Chinese phonetics Conference*, 2009.
- [9] Zeng, Xiaoyu, "Comparative Analysis of 70 Years' Research on Chongqing Dialect Phonetics," *Journal of Chongqing Radio and TV University*, 2013.
- [10] Li, Wang, *The Study on Southwest Mandarin at the Junction of Sichuang and Shaanxi*. Beijing Language and Culture University Master's thesis, 2008.
- [11] Zhou, Zheng. *The Investigation of Ankang Dialects*. Shaanxi People's Educational Publishing House, 2015.
- [12] Huang, Houji. *The Comparative Study on Hanzhong Phonology*. Beijing Language and Culture University Master's thesis, 2008.

Appendix 1: 8 Representative Characters and Fundamental Frequency from Huaping Dialect

yinping		yangping		shangsheng		qusheng	
low 低	167-219	compensate 赔	179-118	ghost 鬼	263-251	move 动	148-142-209
open 开	161-179	complete 齐	164-118	understand 懂	243-227	crime 罪	135-135-212
should 该	141-173	mud 泥	150-112	ancient 古	272-259	odd 怪	136-122-160
book 书	149-165	firewood 柴	161-100	nine 九	252-246	ache 痛	148-148-203
primary 初	176-201	hoe 锄	174-115	bitter 苦	272-242	inch 寸	156-155-242
pig 猪	158-204	eggplant 茄	172-148	grass 草	213-190	near 近	129-129-201
boot 靴	162-193	nose 鼻	167-101	buy 买	204-204	hole 洞	151-144-239
song 歌	149-173	late 迟	166-115	old 老	237-232	tree 树	149-149-227

Appendix 2: 10 Representative Characters and Fundamental Frequency from Ziyang Dialect

yinping		yangping		shangsheng		qusheng	
east 东	138-199	door 门	178-91	ghost 鬼	212-102	move 动	138-130-204
wave 波	144-187	dragon 龙	162-94	understand 懂	207-109	crime 罪	150-122-210
light 灯	143-211	cow 牛	167-91	ancient 古	214-161	odd 怪	140-122-200
ladder 梯	158-191	oil 油	161-100	nine 九	215-104	ache 痛	134-128-205
through 通	139-202	copper 铜	184-91	bitter 苦	224-94	back 后	136-135-204
open 开	136-200	skin 皮	173-83	unite 统	218-114	near 近	141-126-203
sky 天	145-213	joint 节	180-89	buy 买	233-118	four 四	146-121-196
spring 春	146-218	late 迟	170-96	have 有	232-107	half 半	117-109-188

Appendix 3: 8 Representative Characters and Fundamental Frequency from Zhenba Dialect

yinping		yangping		shangsheng		qusheng	
more 多	104-111	eggplant 茄	128-91	fire 火	169-126	mill 磨	89-86-113
song 歌	113-133	except 除	136-70	tile 瓦	127-106	sit 坐	92-89-137
wave 波	124-142	tea 茶	90-73	ancient 古	135-96	pass 过	86-134
boot 靴	132-145	grandma 婆	131-77	bitter 苦	146-127	thank 谢	88-80-122
cock 鸡	128-160	row 排	112-78	five 五	150-128	anger 怒	102-100-153
open 开	125-156	mud 泥	121-71	tiger 虎	155-129	do 做	115-98-126
district 区	134-172	complete 齐	112-69	host 主	160-89	saw 锯	101-93-165
spring 春	112-146	compensate 赔	132-80	buy 买	104-79	half 半	109-103-135