A three-dimensional visualisation of monophthongs for L2[1]

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1. Introduction

How to teach and where to start teaching English pronunciation depends on the non-native learner's standard of English. In general textbooks on English phonetics are written based on a bottom-up graded system as follows: ＜phoneme (vowels, consonants) ＜word (syllable) ＜compound words ＜phrase ＜sentence (clause) ＜passage (paragraph).

Top-down graded instruction emphasises prosodic teaching based on rhythm and timing. However, this is a time-consuming matter more related to fluency, which does not necessarily guarantee to improve pronunciation as a whole. Often the main reason for top-down graded instruction is a lack of basic and proper training such as acquisition of phonemes. Therefore, phonemes are very basic for learning pronunciation and should be taught correctly, utilising symbols at all levels.

1.1. Previous studies of vowel charts

1.1.1. The IPA vowel chart

Teachers in charge of pronunciation in the classroom know that articulatory phonetics is the very basic matter that improves pronunciation as a whole and that, in particular, training the phonemic level is extremely important. For example, there are many vowels in English, compared to the Japanese counterparts (only five). Moreover, there are many other features lying between these languages, for example, sound changes in English which do not occur in Japanese. In Japanese length differentiation is decisively important as a semantic distinction. On the other hand, vowel quality is much more important than duration in English. As a matter of fact, the Japanese often encounter communication problems unless they master these complicated English vowels properly.

1 This paper is based on my presentation for the 1st International Conference of Language, Linguistics and Literature.

Vowels are of the utmost importance among phonemes. Historically, various vowel charts have been invented through impressionistic analysis. The IPA vowel chart as seen in the figure 1[2] has a two-dimensional quadrilateral shape, which was finally accepted after a long history of variations in shape, designed to illustrate abstract vowel locations. The vowel locations imply the height, frontness/backness, and openness/narrowness of the tongue in the production of vowels. This quadrilateral shape is related to psychologically perceptive vowel locations. It has long been used in the classroom to teach English pronunciation. Learners can be aware of abstract relationships between vowels, if they are given sufficient explanation. These facts may prove that it is still useful in a teaching/learning situation.

However, it has some deficiencies as is well known. It does not show lip roundness or lip protrusion (only theoretically).

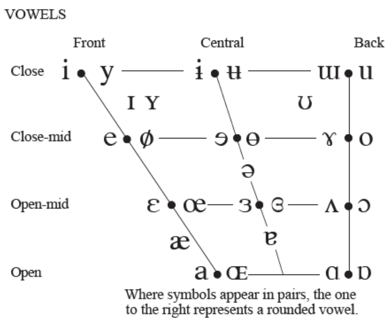

Figure 1　IPA vowel chart

1.1.2. Vowel formant chart

Vocal tract resonances are called formants. The first formant is the most responsive to changes in mouth opening. The second formant is the most responsive to changes within the oral cavity, e.g., tongue backing or lip activity, and the third formant is responsive to front versus back constriction (see p. 98 in [5]).

Based on the IPA vowel chart, a vowel formant chart was formulated utilising actual first (F1) and second (F2) formant values. It is a square shape with two scales on the x and y axes, wherein x is F2 and y F1 as shown in figure 2[3]. In figure 2 the Bark scale is used for F1 and F2 axes so that it fits into the quadrilateral IPA vowel chart better.

This method is square in shape, as is often the case, and a circle is used to cover the area of variance of each vowel. As is known, exactly the same vowel formant values do not reoccur

2 This figure was taken from [6].

3 This figure was taken from [7] (p. 8). The F1 and F2 values were quoted from [3] for the Japanese vowels and from [9] for the Finnish vowels. The mean values of six Japanese males were used for the Japanese vowels and five for the Finnish counterparts.

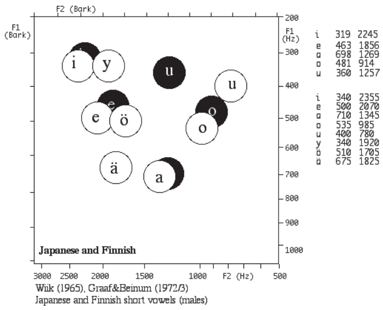

Figure 2 Vowel formant chart for Japanese and Finnish short vowels

and vary every time in any individual's utterances. Therefore, a circular shape for showing the variations of a vowel seems ideal for illustrating the approximate vowel locations in a particular language, and not by using a dot. In this figure the greatest difference between the Finnish (white circles) and Japanese (black circles) vowels is in /u/. It is not clear whether the Finnish /u/ is more lip-rounded, but it is clear from F2 that the lips are in a narrower position than for the Japanese counterpart.

As observed in connection with figure 2, the first formant may represent lip closeness/openness, and the second formant the tongue position (back/front, high/low) and lip protrusion and spreading as may the third formant (F3), which is not on the figure, individuality, and probably lip roundness. The fourth and fifth formants are somewhat stable. This implies that we may have to refer not only to F1 and F2, but also to F3 in order to describe vowel shape more realistically.

Since 1960s speech technologists have been claiming that formant values are not sufficient to represent vowel properties accurately and that spectra should also be calculated in the analysis of vowels. Speech technologists calculate spectra, not formants. For example, in 2007 Asakawa et al. ([1]) illustrated four-dimensional converse quadrilateral shape (4:3:2 in the scale) in order to locate American English vowels by calculating physio-acoustic distances between vowels, unifying tongue height, lip-roundness, frontness/backness of the tongue, and r-colouring. Thus, there has been a discrepancy between phonetic representations and the physio-acoustic counterparts of vowels.

1.2. Research purpose

Formant information is not sufficient to show all the acoustic features of vowels. However, these representations from speech technology and the clinical method are too difficult for the researcher from the humanities, and too impractical for a teaching situation in the classroom, without highly user-friendly applications.

English teachers know from experience that the mastering of vowels is extremely important, especially for such learners of English (L2) as the Japanese, because the number of the vowels is very limited in Japanese. Also, they know that the IPA vowel chart is still very effective when teaching pronunciation. However, the IPA vowel chart is not easy to understand without explanation.

Furthermore, it should be noted that all the above representations are two-dimensional. Thus, I have started the research in order to develop a program which describes the locations of vowels three-dimensionally, utilising computer graphic technology. Teachers and learners need a tool that is effective and easy to use, and that, in addition, provides motivation and is fun to use. It must be a user-friendly program.

2. Method

In the imaging system, each datum is replaced by three axes x, y, and z, in order to grasp three kinds of data, that is, three kinds of information. Compared to the production of conventional graphs, the view is dynamically changed with the result that three-dimensional data becomes visualised at a glance. I applied this system to the visualised three-dimensional formant vowel chart. The user only has to type in the data, that is, three formant real values (F1, F2, F3), and the program automatically presents the vowel(s). Also, a user can move the angle of the axes simply by sliding the mouse, and choose the colour of the background and the colour of the vowels in two-dimensional or three-dimensional representations. The area presenting the vowels fits into the formant values.

The number of vowels depends on the language, as does the quality (formant values) as well. The IPA primary cardinal vowels [i a ɒ u] present the maximum points for lip spreading, lip openness, and narrowness and so form the basis for the four corners of the quadrilateral shape. Thus, vowels of any kind in all languages should fit into this quadrilateral shape. Moreover, the real formant values for any type of vowel in any language should fit into this area. Also, the system offers a selection of from only one vowel to the number of vowels necessary for any particular language. Thus, in the first instance I referred to the values of the axes for F1 and F2 in the IPA chart ([2]). Like a formant vowel chart, the vertical value shows F1 and the horizontal value F2. To show depth F3 was constructed proportionally to F1 and F2. The maximum value for the *y*-axis is 1000 Hz, that for the *x*-axis 3200Hz, and for *z*-axis 3500 Hz. Below, figure 3 shows the IPA primary cardinal vowels (eight)[4] in three-dimensional visualisation (with F1 and F2 values).

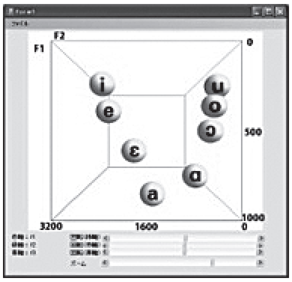

Figure 3 IPA primary cardinal vowels based on F1 and F2

2.1. Choice of two or three formants

This system enables a user to choose only F1 or F2 values, or all F1, F2 and F3 values. Figure 4 shows the five Japanese vowels using F1 and F2 in two-dimensional and figure 5 using F1, F2 and F3 in three-dimensional visualisation.[5] Since figure 4 does not include F3, the size of the circles (=vowels) are exactly alike. On the other hand, F3 is shown in figure 5. Thus, the depicted size of the vowels appears larger or smaller depending on F3, which becomes evident through its difference in depth.

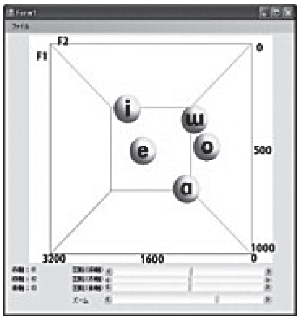

Figure 4 Five Japanese vowels based on F1 and F2

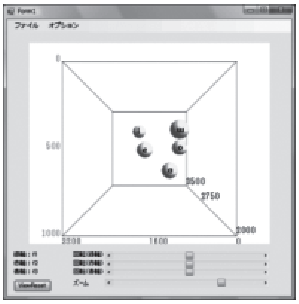

Figure 5 Five Japanese vowels based on F1, F2 and F3

4 The F1 and F2 values were quoted from [2] (p. 154).

5 The F1, F2 and F3 values are the mean values for five Japanese males. The data were taken from [4].

When figure 5 with its three different formants is compared to figure 4 with its two formant types, that is, without the F3 value, figure 4 can more easily be understood at a glance by learners. However, the F3 value is still necessary for showing depth as a referent.

2.2. Colour variation

The user can select a background and symbol colour from a wide selection of colours if they wish. Figure 6 shows the five Japanese vowels in three formants with blue as the background. Figure 7 shows the five Japanese vowels in three formants using pink colour for the phonetic markers.

Figure 6　Blue-shaded background

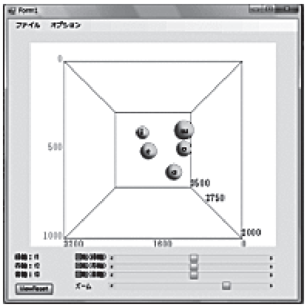

Figure 7　Pink-shaded symbols

2.3. Zooming

The vowels can be enlarged as the user wishes by sliding the ‘zoom’ function. Figure 8 shows the zoomed five Japanese vowels in three formants.

Figure 8　Zoomed vowels

2.4. Viewing angle

The users can freely adjust the viewing angle according to their wishes by sliding the three axes: x, y, and z with the mouse, so that the view of all vowels changes by degree as shown in figures 9 and 10. Figures 9 and 10 show the five Japanese vowels in two settings (without or with F3) viewed from different angles. As can be seen from these two figures, I made the phonetic symbols visible from any angle. The explicit difference between figures 9 and 10 is that the vowel balls are placed at one side because of a lack of F3 information in figure 9 and in figure 10 all the balls are scattered in the space because in this case there is F3 information.

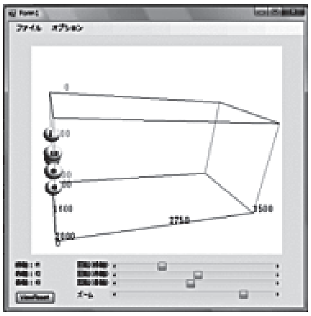

Figure 9　Vowels without F3

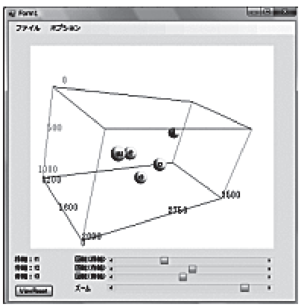

Figure 10　Vowels with F3

2.5. Applications

By applying this program we can compare the gender or age differences of vowel formants. Figures 11, 12 and 13 show ten American English monophthongs uttered by males, females and children[6] respectively, and the representations are based on three formants. Another application could be for comparisons between languages. Also, it is possible to compare one's own monophthongs with a model example. It is sufficient for the realisation of these applications for the user simply to open a file in the notepad.

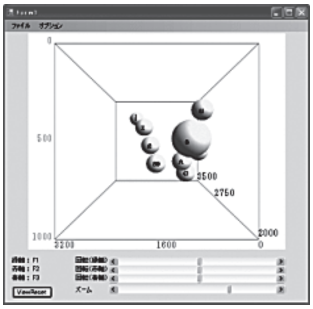

Figure 11　Ten American English monophthongs of males

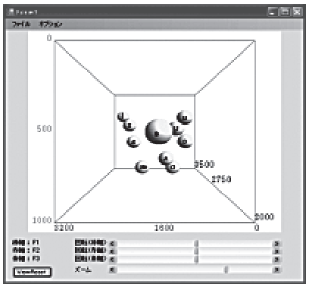

Figure 12　Ten American English monophthongs of females

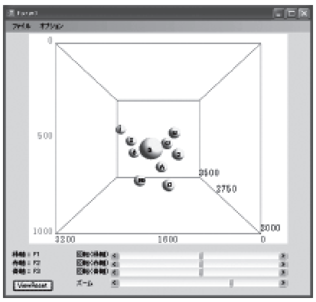

Figure 13　Ten American English monophthongs of children

6 The F1, F2 and F3 values for males, females and children were taken from [8] (p. 183).

3. Summary

To summarise:

(1) A vowel formant is still effective,

(2) The program described in this research could include F3,

(3) Consequently, the learner can study the lip roundedness and lip protrusion,

(4) A user can still study the location of vowels without F3,

(5) A learner can have fun changing colours and angles, and by zooming,

(6) A learner may compare the differences between gender, age, language, etc.,

(7) It is easy to operate.

4. Conclusion

It is expected that this visualisation system will help L2 students motivate for further learning while having fun. For future studies, there is much to do towards developing this three-dimensional vowel chart. For example the following could perhaps be improved upon:

(1) Synchronising the vowel sound,

(2) Simultaneous representations of vowels in more than one language type, of different gender and age, of a model and one's own pronunciation or of diphthongs or triphthongs,

(3) Vowel ball movement in accordance with the real time recording using speech recognition technology.

I anticipate that upon completion of this research, this program will be able to provide learners with a very effective pronunciation training system.

5. Acknowledgements

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