The `vowelchart` package

Vowel charts with Ti*k*Z

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Contents

1 Introduction 2
1.1 Features . . . 2
1.2 Requirements . . . 2
2 Quick start: The general structure 3
3 Options: Properties of the vowel chart 3
3.1 Where options can be set . . . 3
3.2 Shape . . . 4
3.3 Grid style . . . 5
3.4 Size . . . 6
3.5 Colors . . . 7
3.6 Font and font size . . . 8
3.7 Line width, dot size, and arrows . . . 9
4 The commands: Placing vowels 9
4.1 Placement options . . . 9
4.2 `\putvowel` . . . 10
4.3 `\putcvowel` . . . 11
4.4 `\putipavowel` . . . 11
4.5 `\putdiphthong` . . . 13
4.6 `\putipadiphthong` . . . 14
5 Using Ti*k*Z in the vowel chart 15
5.1 Nodes . . . 15
5.2 The coordinate system `vowel cs` . . . 15
5.3 Using the chart's settings in your own code . . . 16
5.4 Further possibilities . . . 16
5.5 Changing the white areas for colored backgrounds . . . 17
6 Compatibility with `vowel` and `pst-vowel` 18
6.1 Moving from `(pst-)vowel` to `vowelchart` . . . 18
6.2 Legacy: absolute coordinates with `\putvowel*` . . . 19
7 A known problem and some solutions 20
8 The mathematics behind it 22
8.1 How `vowelchart` turns relative into real coordinates . . . 22
8.2 From absolute `vowel` coordinates to relative `vowelchart` coordinates . . . 23
9 Examples 24
9.1 Test . . . 28
Appendix: Short reference of commands and options 29
Version history 31

1 Introduction

1.1 Features

The package `vowelchart`, as the name suggests, helps you draw vowel charts for linguistics. It is indebted to the creators of two older packages, whose work it continues:

- `vowel` (2001) by Fukui Rei, distributed with `tipa`, draws the charts with LaTeX-picture-like primitives. Vowels are placed with `\putvowel` and `\putcvowel`.
- `pst-vowel` (2009) by Alan Munn adds PSTricks nodes to `vowel`, so that arrows (e.g. for diphthongs) can be drawn between vowels.

However, the package `vowelchart` differs from the preceding packages in several important respects:

- **Vector graphics:** In `vowel`, the slanted lines consist of many tiny squares, which show up as steps at higher resolutions. In `vowelchart`, every line is a real vector path and stays smooth at any zoom level.
- **Nodes and Ti*k*Z:** Every vowel is a Ti*k*Z node. You can draw arrows, shaded areas and annotations with ordinary Ti*k*Z commands in the same picture, using a special coordinate system that works for every chart shape.
- **Exact size:** The chart can be given an exact width or height.
- **More shapes and grids:** In addition to the shape options of `vowel`, there are a symmetric and a slanted quadrilateral, and all four corners can be set by hand. Apart from the grid styles of `vowel`, you can have a triangular central zone without a middle line or a central column resulting in a 3×3 division.
- **Relative coordinates:** Vowels are placed with abstract coordinates that follow the shape of the chart, so the same code works in every shape.
- **Convenient commands:** `\putipavowel` places a vowel simply defined by its IPA symbol (with Unicode or X-SAMPA input) at its usual position in the chart, `\putdiphthong` draws a diphthong arrow between two positions, and `\putipadiphthong` draws it between two vowels given by their IPA symbols or between any mixture of IPA vowels and Ti*k*Z nodes.
- **Colors and line widths:** Foreground and background colors, the line width and the dot size can be set for each chart.
- **Settings at several levels:** All options can be given for a single chart, for all following charts in a document, or as package options (Section 3.1).

1.2 Requirements

The package loads `tikz`, `contour` and `xparse`, and needs a LaTeX kernel from 2020 or later (expl3). With XeLaTeX or LuaLaTeX, choose a font that contains the IPA symbols (for instance Libertinus, Charis SIL or DejaVu). With pdfLaTeX, the IPA characters must be made available by an encoding or font package.

If you load `vowelchart` together with `vowel` or `pst-vowel`, load it *after* them (see Section 6.2).

2 Quick start: The general structure

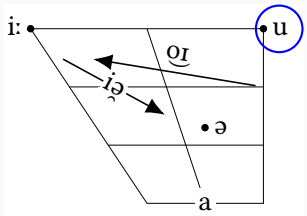
In order to draw vowel charts, you first have to tell LaTeX to use this package:

```
\usepackage{vowelchart}
```

If the package `vowelchart` is not part of your LaTeX distribution, all you have to do is copy the file `vowelchart.sty` to the same folder as your main `.tex` file.

Then you can create an environment `vowelchart`, which automatically draws a chart. Within this environment, you can then use any of the commands `\putvowel`, `\putcvowel`, `\putipavowel`, `\putdiphthong`, and `\putipadiphthong` to place vowels on the chart. You can also use Ti*k*Z commands to draw in the chart. See the following example.

```
\begin{vowelchart}
  \putvowel[r]{ə}{1.3}{1.7}
  \putcvowel[l]{i:}{1}
  \putipavowel{u}[vowelu]
  \putipavowel{'a'}
  \putdiphthong[diphlabelpos=on]{iə̯}{0.1}{0.5}{0.9}{1.5}
  \putipadiphthong{*}{o}{I}
  \draw[blue, thick] (vowelu) circle (0.4);
\end{vowelchart}
```



You do not have to type all of this by hand. The *Vowel Chart Maker* at https://danielbuncic.github.io/vowelchart/ is a web page that works in your browser, without LaTeX and without an internet connection once it has been loaded. You build the chart by clicking on vowels, drawing arrows and shapes, and choosing sizes and colors, and it gives you the code for this package; the same chart can also be saved as an SVG or PNG graphic. It can also read LaTeX code back in, so that you can continue to edit existing charts (everything that it does not understand is kept as it is). The *Maker* covers almost all the commands and options of this package (except for some rather special ones).

You can change the appearance of the vowel chart by adding parameters. The options you have for this, and the places where you can set them, are laid out in Section 3. The exact syntax and properties of the commands for placing vowels are presented in Section 4. Finally, since the vowel chart is a `tikzpicture`, you can use Ti*k*Z commands to easily add graphical elements (and text) to the chart, see Section 5.

3 Options: Properties of the vowel chart

3.1 Where options can be set

All options are given as a comma-separated list of keys, optionally with values (`key=value`). Such a list can be used at three levels:

```
% 1. for a single chart
\begin{vowelchart}[<options>]
  <vowel commands and TikZ commands>
\end{vowelchart}

% 2. for all following charts
\vowelchartset{<options>}

% 3. for all charts of the document, when loading the package
\usepackage[<options>]{vowelchart}
```

At the beginning of every chart, first the options given when loading the package and by `\vowelchartset` are applied, in the order in which they were given, and then the options of the chart itself. Within a list, options are processed from left to right. Thus more specific settings always override more general ones, and later settings override earlier ones. Example:

```
\usepackage[slanted, fg=blue!50!black]{vowelchart}   % default for all charts
...
\vowelchartset{linewidth=.3pt, fontsize=10pt}        % for all following charts
...
\begin{vowelchart}[normal, fg=black, width=5cm]      % this chart only
```

Some remarks:

- `\vowelchartset` acts globally, even inside a group, and the settings accumulate. You cannot delete a default, but you can override it in a chart with the opposite option, e.g. `normal` for the default shape, `ipanew` for the default grid style, `four` for the default number of vertical levels, or `bg=white`. An empty value (e.g. `labelbg=`) restores the default of the colors for labels (Section 5.5).
- Shape options set all four corners, so a predefined shape given later overrides corners given before (Section 3.2).
- A bare dimension such as `6cm` is a shorthand for `width=6cm`.
- Values containing a comma have to be put in braces, e.g. `tl={0,0.5}`.

A complete list of all options with their defaults is given in Section 9.1.

3.2 Shape

The shape is defined by four corners: top left (`tl`), top right (`tr`), bottom left (`bl`) and bottom right (`br`). The unit is one quarter of the width of the default chart; the y axis points downwards. The standard shapes (shown in Figure 1 and Table 1) set all four corners.

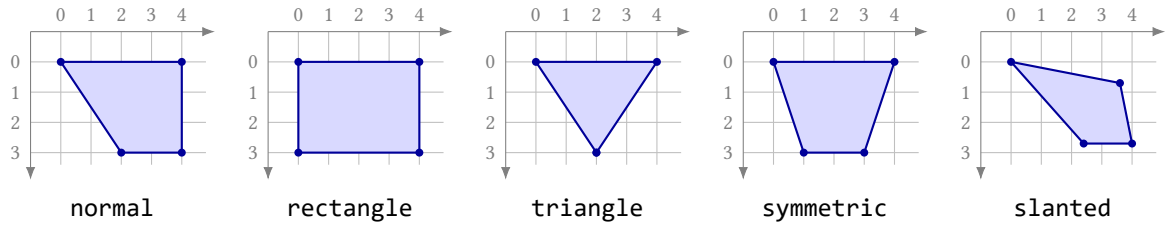


Figure 1: The coordinate system used for defining the corners (the y axis points downwards)

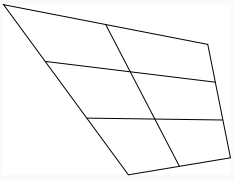
Option	tl	tr	bl	br
normal (default)	0, 0	4, 0	2, 3	4, 3
rectangle	0, 0	4, 0	0, 3	4, 3
triangle	0, 0	4, 0	2, 3	2, 3
symmetric	0, 0	4, 0	1, 3	3, 3
slanted	0, 0	3.6, 0.7	2.4, 2.7	4, 2.7

Additionally, you can set the corners of the quadrangle manually.

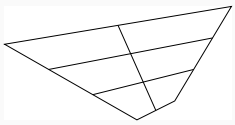
```
tl={<x>,<y>}   tr={<x>,<y>}   bl={<x>,<y>}   br={<x>,<y>}
```

Corners not mentioned keep the values of the chosen shape, so you can start from a standard shape and change a single corner. Since a shape option overwrites *all* four corners, it has to come before individual corner options. The braces are required, because the comma would otherwise separate options. Values are evaluated by pgfmath, so mathematical expressions are allowed.

```
\begin{vowelchart}[slanted, bl={2.2,3},
↪  width=3cm]\end{vowelchart}\quad
```



```
\begin{vowelchart}[tl={0, 2/3}, tr={4, 0}, bl={7/3, 2},
↪  br={3, 5/3}, width=3cm]\end{vowelchart}
```



3.3 Grid style

Option	Lines
none	nothing at all, not even the outline is visible (see below)
plain	outline only
simple	outline and horizontal line(s)
ipanew (default)	simple plus a vertical center line (as in the current IPA chart)
centralzone	simple plus a triangular central zone
standard	centralzone plus a vertical line through the middle of the central zone (the name standard has been kept from the vowel package)
centralcol	simple plus two vertical lines, resulting in a 3 × 3 division of the vowel space
four (default)	four heights are distinguished (i.e. two horizontal middle lines are drawn in all styles except plain)
three	only three heights (i.e. only one horizontal middle line)

If you need additional lines, you can easily add them with \draw commands, using the convenient relative coordinates explained in Section 4.2 (see Figure 2) via the coordinate system vowel cs (Section 5.2).

With none, nothing is drawn automatically, so you can draw only a part of the chart yourself with \draw and the relative coordinates. The picture contains only what you draw (plus the background), as in this example, which shows only the bottom row of the chart:

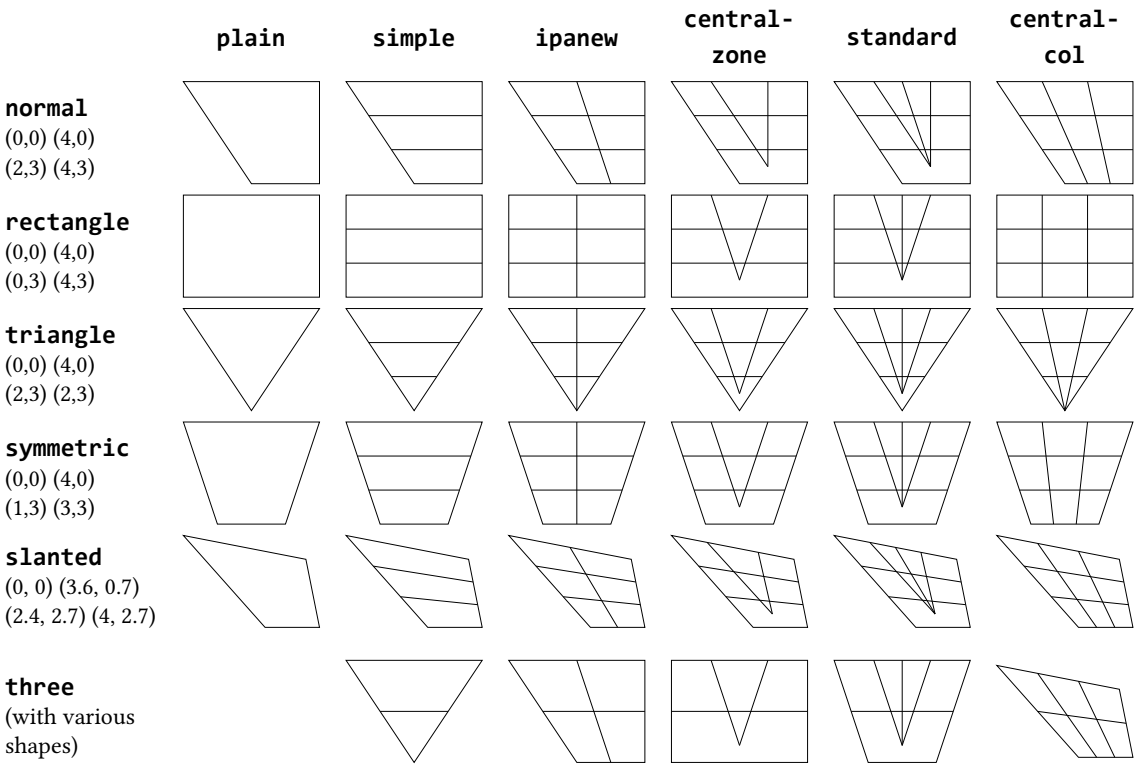
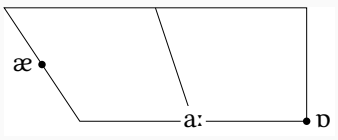


Table 1: Options for chart shapes and grid styles

```
\begin{vowelchart}[none, width=6cm]
  \draw (vowel cs: h=0, v=2) -- (vowel cs: h=2, v=2) --
  ↪  (vowel cs: h=2, v=3) -- (vowel cs: h=0, v=3) -- cycle;
  \draw (vowel cs: h=1, v=2) -- (vowel cs: h=1, v=3);
  \putipavowel[a:]{'a'}
  \putipavowel{ɒ}
  \putipavowel{æ}
\end{vowelchart}
```



`width` and `height` still refer to the *whole* chart, so a part of it is correspondingly smaller than the width you give.

Grid styles and shapes are independent of each other and can be combined freely. Combinations of shapes and grid styles are shown in Table 1.

3.4 Size

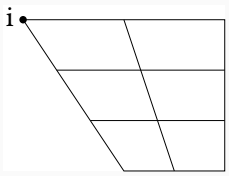
```
width=<dimension>     height=<dimension>     <dimension>
```

`width` sets the exact width and `height` the exact height of the quadrilateral grid (excluding overhanging labels and dots). A bare dimension such as `[6cm]` is a shorthand for `width`. There is only one scale for both directions; the chart is never distorted. If both are given, the last one wins. The default is `width=8em`.

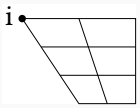
Because `em` refers to the font size of the chart (the font size at the beginning of the environment, after applying the options `font` and `fontsize`), commands such as `\small` or `\Large` before the chart

scale it together with its symbols unless the size is set with an absolute measure of length. The default line widths and dot sizes are absolute (Section 3.7).

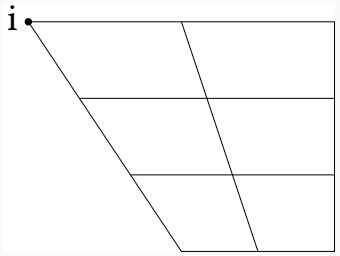
```
\begin{vowelchart}[height=2cm]
  \putipavowel{i}
\end{vowelchart}
```




```
\begin{vowelchart}[width=1.5cm]
  \putipavowel{i}
\end{vowelchart}
```




```
{\Large
  \begin{vowelchart}
    \putipavowel{i}
  \end{vowelchart}
}
```



3.5 Colors

Option	Colors
`fg`	the foreground color of lines, dots and labels (default: the current text color, usually black)
`bg`	the background color (default: white)
`labelbg`	the color of the area cleared behind labels (default: = `bg`; can also be `off`; see Section 5.5)
`contour`	the color of the contour around labels (default: = `labelbg`; can also be `off`; see Section 5.5)

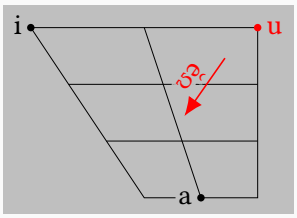
By default, everything is drawn in the current text color on a white background. You can change this by giving color definitions in the variables `bg` for the background color and `fg` for the foreground color. The background color is used for a rectangle behind the whole chart and also for the areas that clear the lines around the labels; it should therefore be the color of the surrounding if you use a transparent-looking chart. Both options accept all color expressions of `xcolor`, e.g. `bg=cyan!15`.

```
bgmargin=<dimension>
```

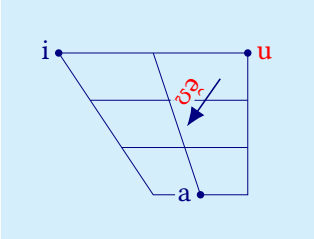
By default, the background rectangle ends exactly at the outermost elements of the chart, so that a chart with a white background fits seamlessly into a white page. If the background differs from the color of the surrounding, this looks cramped, and you can add a margin with `bgmargin`. It is applied on all four sides (default: `0pt`). The option is called `bgmargin` because `margin` is already used for the width of the contour around labels (Section 7).

Note that you can use color within vowel charts as well. If you use `\color` before one of the commands for placing vowels, both the dot or arrow and the label will appear in this color. If you want to change the color of the label separately from the corresponding dot or arrow, you can use `\color` or `\textcolor` within the label argument of the `\put`… command. Inside the chart, `\color{vowelchartfg}` restores the foreground color of the chart (Section 5.3).

```
\begin{vowelchart}[bg=lightgray, bgmargin=3pt, width=3cm]
  \putipavowel{i}
  {\color{red}
    \putipavowel{u}
    \putdiphthong{ʊə̯}{1.7}{0.5}{1.1}{1.6}
  }
  \putipavowel{a'}
\end{vowelchart}
```

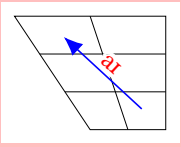



```
\begin{vowelchart}[fg=blue!50!black, bg=cyan!15,
↪  bgmargin=0.5cm, width=2.5cm]
  \putipavowel{i}
  \putvowel[r]{\color{red} u}{2}{0}
  \putdiphthong{\textcolor{red}{ʊə̯}}{1.7}{0.5}{1.1}{1.6}
  \putipavowel{a'}
\end{vowelchart}
```




```
\colorbox{pink}{%
  \begin{minipage}{5cm}
    \small A standard vowel chart in a surrounding with a
    ↪  different background color: \medskip \\
    \begin{vowelchart}[width=2cm, bgmargin=5pt]
      \color{blue}
      \putdiphthong{\textcolor{red}{aɪ}}{1.5}{2.5}{0.5}{0.5}
    \end{vowelchart}
  \end{minipage}
}
```

A standard vowel chart in a surrounding with a different background color:

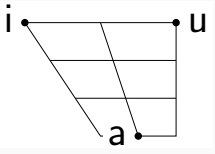


3.6 Font and font size

```
font=<commands>          fontsize=<dimension>
```

The option `font` executes the given font commands at the beginning of the chart, e.g. `font=\large`, `font=\sffamily` or `font=\itshape\small`. `fontsize` sets a fixed size such as `fontsize=12pt` (the baseline skip becomes 1.2 times the size). Both can be combined; if they set the same property, the later one wins. The font applies to all labels and to the nodes drawn inside the chart. Lengths given in `em` or `ex` (the default width, the distances around labels and the line width if you give it in `em`) refer to this font size, so the whole chart scales with it. Instead of the options, you can also put size commands such as `\Large` before the environment.

```
\begin{vowelchart}[2cm, font=\sffamily, fontsize=16pt]
  \putipavowel{i}
  \putipavowel{a'}
  \putipavowel{u}
\end{vowelchart}
```

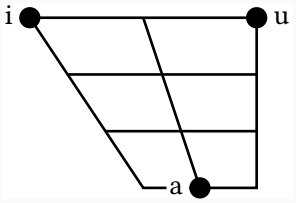


3.7 Line width, dot size, and arrows

```
linewidth=<dimension>        dotsize=<dimension>
arrowwidth=<dimension>       arrowhead=<dimension>
```

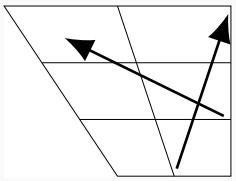
`linewidth` sets the width of the lines of the chart (default: `0.2pt`), `dotsize` the radius of the dots next to vowels placed with `[l]` or `[r]` (default: `1.4pt`). The diphthong arrows of `\putdiphthong` and `\putipadiphthong` have their own settings, which do not depend on the line width of the chart: `arrowwidth` is the line width of the arrows (default: `0.6pt`), and `arrowhead` is the size, i.e. the width, of the arrowheads (default: `6pt`; a head is 1.2 times as long as it is wide). All four are absolute unless you give them in `em`. (The values are available for your own Ti*k*Z code as `\vowelchartline`, `\vowelchartdot`, `\vowelchartarrow` and `\vowelcharthead`; see Section 5.3).

```
\begin{vowelchart}[width=3cm, linewidth=1pt, dotsize=4pt]
  \putipavowel{i}
  \putipavowel{u}
  \putipavowel{a'}
\end{vowelchart}
```



The arrows are not affected by `linewidth`. Their line width and the size of their heads are set with `arrowwidth` and `arrowhead`:

```
\begin{vowelchart}[width=3cm, arrowwidth=1pt, arrowhead=9pt]
  \putipadiphthong{}{ɔ}{ɪ}
  \putipadiphthong{}{a'}{u}
\end{vowelchart}
```



Further options tune the white areas around the labels and are described in Section 7, and another option is described in Section 4.6.

4 The commands: Placing vowels

4.1 Placement options

The commands `\putvowel` and `\putcvowel` take a list of options in their first optional argument. The following keys decide how the symbol is placed:

`x` (default)	symbol centered on the position, no dot
`l`	dot at the position, symbol to the left of the dot
`r`	dot at the position, symbol to the right of the dot

In addition, the keys `labelbg=<color|off>` and `contour=<color|off>` change the colors of the area cleared behind the label (Section 5.5). The keys are separated by commas (e.g. `\putvowel[l, labelbg=yellow]{e}{0}{1}`).

If you leave the *vowel label empty*, only the dot is drawn, which is useful for marking positions (see the example in Section 9).

Each command also accepts a trailing optional *node name*. The symbol becomes a Ti*k*Z node of that name (Section 5.1). Small horizontal corrections of a single symbol can be made by adding `\hspace` inside the symbol argument.

4.2 \putvowel

```
\putvowel[<options>]{<symbol>}{<h>}{<v>}[<node name>]
```

This command places a symbol at the abstract position (h, v). Vowels are not placed with absolute coordinates, but with relative coordinates that follow the shape of the chart, so the same code works in every shape:

- h runs from 0 (left edge) to 2 (right edge)
- v runs from 0 (top edge) to 3 (bottom edge).

Thus $h = 1$ is always on the center line and $v = 2$ is always at the height of cardinal [ɛ] and [ɔ], whatever the shape. Values outside the ranges are allowed (e.g. $h = -0.5$ is left of the chart). The same coordinates are used by `\putdiphthong` and by the Ti*k*Z coordinate system `vowel cs` (Section 5.2).

Figure 2 marks the v values (blue, along the left and right edges) and the h values (red, along the top and bottom edges) in all five predefined chart shapes and in one user-defined shape.

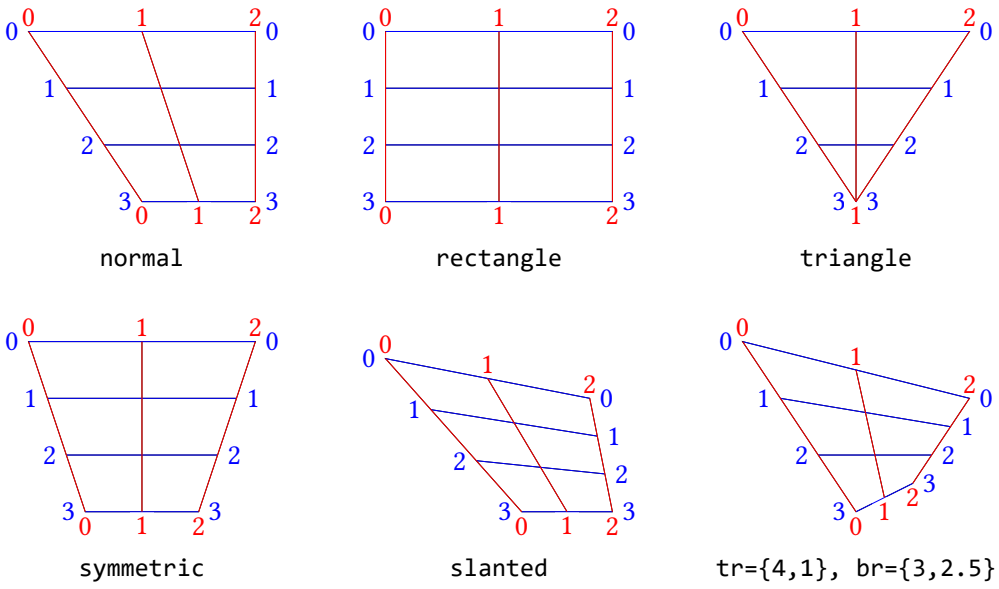
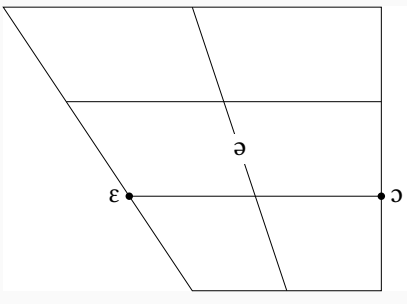


Figure 2: The relative coordinate system, independent of chart shape

If you use the shape option `triangle` and you want to place a vowel at the very bottom at $v = 3$, the h coordinate, logically, has no effect; however, by setting $h = 1$ anyway you ensure that this will still be an open *central* vowel if the chart is ever displayed in a different shape.

Example:

```
\begin{vowelchart}[width=5cm]
  \putvowel[l]{ɛ}{0}{2}[vowele]
  \putvowel[r]{ɔ}{2}{2}
  \putvowel{ə}{1}{1.5}
\end{vowelchart}
```

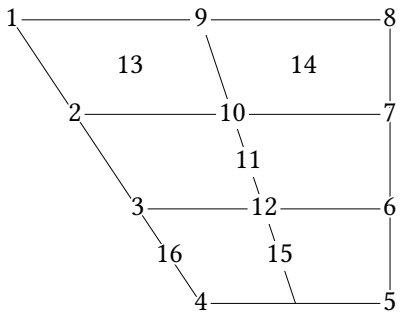


For charts created with `vowel`, a legacy variant with absolute coordinates exists (Section 6.2).

4.3 \putcvowel

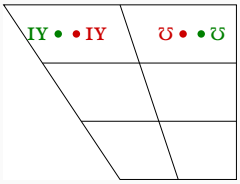
```
\putcvowel[<options>]{<symbol>}{<n>}[<node name>]
```

This command, which is exactly the same as in the vowel package, places a symbol at cardinal position $n = 1, \ldots, 16$. Positions 1–8 are those of Daniel Jones's cardinal vowels; 9–16 are extended positions for the other vowels of the IPA chart. The default node name is vn.



Note that the positions 13 and 14 (for ɪ, ʏ, and ʊ) do not correspond to the current IPA chart. The vowel package places these vowels horizontally halfway between the edge and the middle line, i.e. at the relative positions $h = \frac{1}{2}$ and $h = 1\frac{1}{2}$; the current IPA positions, however, are $h = \frac{1}{3}$ and $h = 1\frac{2}{3}$, respectively.[1] For reasons of downward compatibility, \putcvowel places ɪ/ʏ/ʊ at the same positions as in vowel. For the correct IPA positions, use \putipavowel (Section 4.4), as in the following example.

```
\begin{vowelchart}[labelbg=off, contour=off]
  \color{red!80!black} % positions in vowel package
  \putcvowel[r]{ɪʏ}{13}
  \putcvowel[l]{ʊ}{14}
  \color{green!50!black} % current IPA positions
  \putipavowel[l][ɪʏ]{I}
  \putipavowel[r][ʊ]{U}
\end{vowelchart}
```



4.4 \putipavowel

```
\putipavowel[<options>][<label>]{<IPA or X-SAMPA symbol>}[<node name>]
```

This command places a vowel at its place in the IPA chart. It also typesets the IPA symbol (even if your input is X-SAMPA); if you want something else to appear (e.g. a length mark or brackets), put it in the optional <label>, which replaces the default symbol. The shape of the chart does not matter. For symbols that share a position, the dot is at the same place and the symbols stand on its left (unrounded) or right (rounded) side; ə and ɐ normally have no dot.

The command has two optional arguments before the symbol. If only one is given, it is the <label>. If two are given, the first one holds the <options> for this vowel and the second one the <label>, which may be empty ([]) to draw only the dot. If you want to give options but keep the default label, repeat the symbol as the label, e.g. \putipavowel[labelbg=yellow][e]{e}.

[1] In the IPA charts from 1989 and 1993, ʊ (but not ɪ/ʏ) had indeed been placed at this halfway position; however, since 1996, all three vowel symbols have been in their current places (see the historical charts at the IPA website).

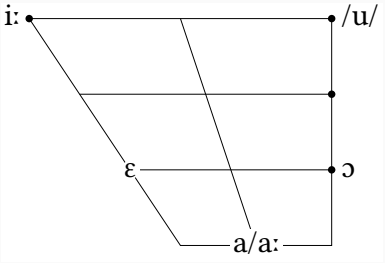
IPA	Accepted input	h	v	dot
i	`i`	0	0	l
y	`y`	0	0	r
ɨ	`ɨ, 1`	1	0	l
ʉ	`ʉ, u-, \}`	1	0	r
ɯ	`ɯ, M`	2	0	l
u	`u`	2	0	r
ɪ	`ɪ, I`	0.33	0.5	l
ʏ	`ʏ, Y`	0.33	0.5	r
ʊ	`ʊ, U`	1.67	0.5	r
e	`e`	0	1	l
e (mid)	`e'`	0	1.5	l
ø	`ø, 2`	0	1	r
ø (mid)	`ø', 2'`	0	1.5	r
ɘ	`ɘ, @-`	1	1	l
ɵ	`ɵ, 8`	1	1	r
ɤ	`ɤ, 7`	2	1	l
o	`o`	2	1	r
o (mid)	`o'`	2	1.5	r
ə	`ə, @`	1	1.5	–
ə (unrounded)	`ə', @'`	1	1.5	l
ə (rounded)	`'ə, '@`	1	1.5	r
ɛ	`ɛ, E`	0	2	l
ɛ (mid)	`ɛ', E'`	0	1.5	l
œ	`œ, oe, 9`	0	2	r
œ (mid)	`œ', oe', 9'`	0	1.5	r
ɜ	`ɜ, 3`	1	2	l
ɞ	`ɞ, 3-`	1	2	r
ʌ	`ʌ, V`	2	2	l
ɔ	`ɔ, O`	2	2	r
ɔ (mid)	`ɔ', O'`	2	1.5	r
æ	`æ, ae, \{`	0	2.5	l
æ (open)	`æ', ae', \{'`	0	3	l
ɐ	`ɐ, 6`	1	2.5	–
ɐ (unrounded)	`ɐ', 6'`	1	2.5	l
ɐ (rounded)	`'ɐ, '6`	1	2.5	r
a	`a`	0	3	l
a (central)	`a'`	1	3	l
a (central, no dot)	`'a'`	1	3	–
ɶ	`ɶ, &, OE`	0	3	r
ɑ	`ɑ, A`	2	3	l
ɒ	`ɒ, Q`	2	3	r

Table 3: Predefined IPA vowels

The position of the symbol is determined by the input in the obligatory argument, which can be the IPA symbol in Unicode (works in XeLaTeX and LuaLaTeX) or the corresponding X-SAMPA code (with a few exceptions due to illegal characters). The input `a'`, `ae'`, `e'`, etc. selects the non-canonical but widely practiced use of [a] for an open *central* vowel and of [æ] for an *open* front vowel and places e, ɛ, o, ɔ, ø and œ as *mid* vowels. You can also place ə and ɐ on the left or right of a dot by using `'`. See Table 3 for all possible input characters. An unknown symbol in this argument raises an error.

The `<options>` in the first of the two optional arguments can contain `labelbg` and `contour` (Section 5.5), the settings listed in Table 5, and `l`, `r` or `x`, which override the position of the label that is predefined for the symbol.

```
\begin{vowelchart}[width=4cm, font=\large]
  \putpavowel[i:]{i}
  \putpavowel[/u/]{u}[vu]
  \putpavowel{O}
  \putpavowel[a/a:]{'a'}
  \putpavowel[]{o} % empty label → only dot
  \putpavowel[x][ɛ]{E} % options, then label
\end{vowelchart}
```



4.5 `\putdiphthong`

```
\putdiphthong[<TikZ options>]{<label>}{<h1>}{<v1>}{<h2>}{<v2>}[<node name>]
```

This draws an arrow from (h_1, v_1) to (h_2, v_2) in the relative coordinates (see Section 4.2). The optional label runs along the arrow, centered, always readable: Ti*k*Z turns the text by $180°$ if it would be upside down, so it stands to the right of an arrow pointing to the upper left and to the left of an arrow pointing to the upper right. The label is protected from the lines of the chart by a contour (Section 7). Use `{}` as the label for an arrow without label.

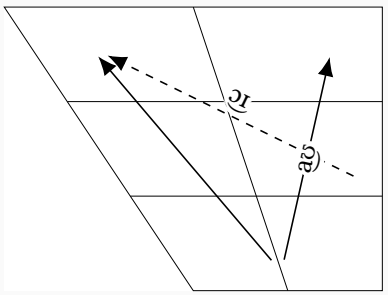
The first optional argument holds Ti*k*Z options for this one arrow; besides the usual Ti*k*Z keys, it accepts `labelbg` and `contour` (Section 5.5). Furthermore, the position of the label relative to the arrow is set with the option `diphlabelpos`, which can be given here, in the properties of the chart, with `\vowelchartset`, or when loading the package (Section 3.1):

```
diphlabelpos=above|below|on
```

`above` (the default) puts the label on the upper side of the arrow, `below` on the lower side, `on` puts the label on the arrow so that the arrow runs through the middle of the x-height (the arrow is interrupted by the label's contour, Section 7).

The `<node name>` belongs to the label node in the middle of the arrow. If you give a name but no label, an empty node of that name is placed in the middle of the arrow; with neither, no node is created.

```
\begin{vowelchart}[width=5cm]
  \putdiphthong{}{0.95}{2.7}{0.35}{0.5} % no label
  \putdiphthong[dashed]{ɔ͡ɪ}{1.8}{1.8}{0.4}{0.5}
  \putdiphthong[diphlabelpos=on]{a͡ʊ}{1.05}{2.7}{1.7}{0.5}
\end{vowelchart}
```



The appearance of arrow and label is controlled by these Ti*k*Z styles:

```
\tikzset{
  vc diph label/.style={sloped, midway, inner sep=0pt},
  vc diph above/.style={above=0.5pt},   % used by diphlabelpos=above
  vc diph below/.style={below=0.15em},  % used by diphlabelpos=below
  vc diph on/.style={anchor=base},      % used by diphlabelpos=on}
}
```

You can redefine them with `\tikzset`, e.g. `\tikzset{vc diph label/.append style={pos=0.35}}` (label closer to the start). `vc diph` can also be used for your own arrows between nodes.

4.6 `\putipadiphthong`

```
\putipadiphthong[<TikZ options>]{<label>}{<start>}{<end>}[<node name>]
```

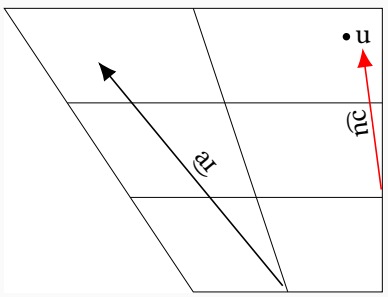
This command works like `\putdiphthong`, but start and end of the arrow are not given as numbers. Each of them is either

- an IPA or X-SAMPA symbol from Table 3 (e.g. `a'`, `I`, `ʊ`): the arrow starts or ends at the position of this vowel in the IPA chart, even if no vowel has been placed there; or
- a Ti*k*Z coordinate *in parentheses*: a node such as `(vu)`, a node with anchor such as `(vu.south)`, `(vowel cs:h=1,v=2)` or `(2,-1)`.

The two kinds can be mixed, e.g. to draw an arrow from a node of your own to an IPA vowel. The parentheses decide which kind is meant, so a node named `i` cannot be confused with the vowel i.

The label * is replaced by the two IPA symbols of the start and the end, joined by the tie bar (U+035C) that is used in the transcription of diphthongs, as in *a͡ɪ*. This works only if both ends are symbols. The tie is stored in the macro `\vowelchartdiphtie`; `\renewcommand\vowelchartdiphtie{}` removes it.

```
\begin{vowelchart}[width=5cm]
  \putipadiphthong{*}{a'}{I}
  \putvowel[r]{u}{1.8}{0.3}[vu]
  \putipadiphthong[red,
  ↪  diphlabelpos=below]{ɔ͡u}{0}{(vu.south)}
\end{vowelchart}
```



Arrows that end at an IPA position are shortened at both ends by the length given in the option

```
ipashorten=<dimension>          % default: 3pt
```

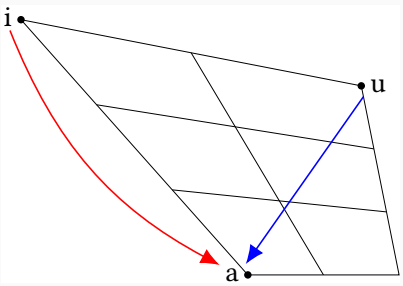
so that they do not touch the dot or the vowel at this position. Ends at nodes or coordinates are not shortened beyond the 1 pt of the style `vc diph`. For a single arrow, you can override this with Ti*k*Z options, e.g. `\putipadiphthong[shorten >=0pt]{...}{a'}{I}`.

5 Using Ti*k*Z in the vowel chart

Since the chart is a `tikzpicture`, everything Ti*k*Z offers is available inside the environment. This section explains how to refer to positions and nodes in the chart and which settings of the chart you can use in your own code.

5.1 Nodes

```
\begin{vowelchart}[slanted, width=5cm]
  \putipavowel{i}[vi]
  \putipavowel{u}[vu]
  \putipavowel{a}[va]
  \draw[vc diph, red]  (vi.south) to[bend right=20] (va.north
  ↪  west);
  \draw[vc diph, blue] (vu.south west) -- (va.north east);
\end{vowelchart}
```



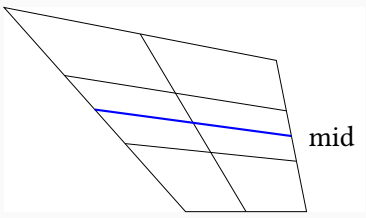
Without a name, the symbol gets an automatic node name (`vcauto1`, `vcauto2`, ...); `\putcvowel` names its nodes `v1`, ..., `v16` by default. These names should not be used for nodes of your own. Nodes are local to their picture, so the same names may be used in different charts. Use only ASCII letters and digits in node names (no dot, colon or comma). A node is the symbol's *label* (a box one `ex` high, with its baseline half an `ex` below the dot), not the dot. If a vowel should be known under a second name, use Ti*k*Z's `\pgfnodealias{<new name>}{<name>}` after placing it.

5.2 The coordinate system `vowel cs`

```
(vowel cs:h=<h>, v=<v>)          (vowel cs:x=<h>, y=<v>)
```

This is a Ti*k*Z coordinate system with the relative coordinates of Section 4.2 (h from 0 to 2 across, v from 0 to 3 down, see Figure 2). It can be used wherever Ti*k*Z expects a coordinate, and it follows the shape and size of the chart. `x` and `y` are synonyms of `h` and `v`; missing values are 0. It works only inside `vowelchart`. With `\usetikzlibrary{calc}`, offsets are possible: `($(vowel cs:h=1,v=1)+(0,-.3)$)`.

```
\begin{vowelchart}[slanted, width=4cm]
  \draw[blue, thick]
  (vowel cs:h=0,v=1.5) -- (vowel cs:h=2,v=1.5);
  \node[anchor=west, xshift=1mm]
  at (vowel cs:h=2,v=1.5) {mid};
\end{vowelchart}
```



Plain Ti*k*Z coordinates (x, y) also work inside the chart, but they do not follow the shape. Their unit is one quarter of the width of the default shape, and the y axis points *upwards*, so that the chart lies

at negative y values: a corner given as `br={4,3}` is the point `(4,-3)`. Figure 3 shows this absolute coordinate system for the predefined shapes. Use `vowel cs` for everything that should stay in place if the shape changes.

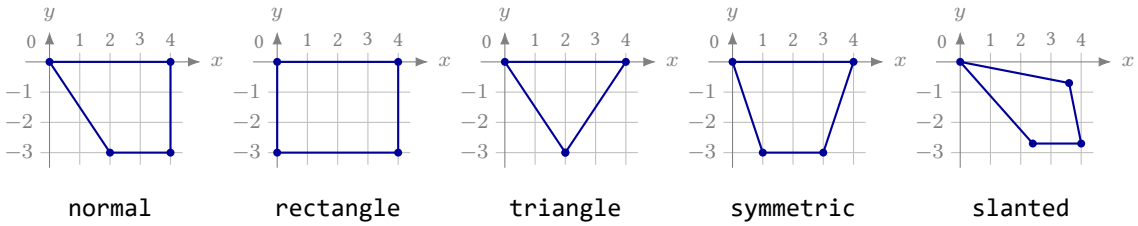


Figure 3: The absolute coordinate system for Ti*k*Z commands inside a `vowelchart`

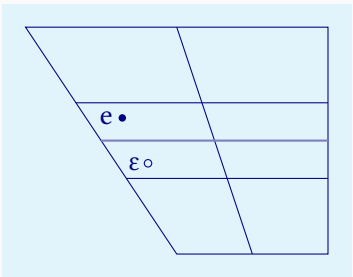
5.3 Using the chart's settings in your own code

Inside the environment, the settings of the chart are available under the following names. Ti*k*Z commands that use them follow any change of design automatically.

Name	Kind	Meaning (set by)
`\vowelchartline`	length	line width of the chart (`linewidth`)
`\vowelchartdot`	length	radius of the dots (`dotsize`)
`\vowelchartarrow`	length	line width of the diphthong arrows (`arrowwidth`)
`\vowelcharthead`	length	size (width) of the arrowheads (`arrowhead`)
`vowelchartfg`	color	foreground color (`fg`; default: the text color at the beginning of the chart)
`vowelchartbg`	color	background color (`bg`)
`vc bg`	style	fills with the background color: `\node[vc bg]{...}`
`vc diph`, `vc diph label`	styles	arrows and arrow labels (Section 4.5)
`\vowelchartdiphtie`	macro	tie bar of automatic diphthong labels (Section 4.6)
`\vowelhunit`, `\vowelvunit`	lengths	the unit of the chart (for legacy charts, see Section 6.2)

The colors and lengths hold the values set by the options (or their defaults), so they are only meaningful inside the environment. After you have changed the color with `\color`, `\color{vowelchartfg}` restores the chart's foreground color.

```
\begin{vowelchart}[fg=blue!50!black, bg=cyan!10,
↪  bgmargin=0.3cm, linewidth=.4pt, width=4cm]
  \draw[line width=2\vowelchartline, vowelchartfg!50]
  (vowel cs:h=0,v=1.5) -- (vowel cs:h=2,v=1.5);
  \putvowel[l]{e}{0.3}{1.2}
  \draw[vowelchartfg] (vowel cs:h=0.3,v=1.8) circle
  ↪  (\vowelchartdot);
  \putvowel[x]{ɛ}{0.17}{1.8}
\end{vowelchart}
```



5.4 Further possibilities

Here are just a few more ideas what you can do with a vowel chart and Ti*k*Z:

- **Color**: put `\color` or a group before the chart, (e.g. `{\color{gray}\begin{vowelchart} ... \end{vowelchart}}`), to color lines, dots and symbols (or use the option `fg`). Inside the chart, `\color` or a `scope` colors what follows.

- **Shading and highlighting**: fill regions with `\fill[blue, opacity=.15] (vowel cs:h=0,v=0) -- ... -- cycle;`. Labels that are placed on a colored area can be given the same background (Section 5.5).
- **Annotations**: `\node` with `vowel cs`, or placed relative to the vowel nodes, e.g. `(voweli.north)`.
- **Arrows and curves**: `\draw` between nodes or coordinates, with `to[bend left]`, `dashed`, arrow tips from `arrows.meta`, etc.
- **Offsets**: with the `calc` library, use `($(vowel cs:h=1,v=1)+(0,-.3)$)`.
- **Styles**: change `vc diph` and `vc diph label` globally (Section 4.5).

Note that `\begin{vowelchart}` takes no Ti*k*Z options; use `\tikzset` or scopes for global settings. The size of the chart cannot be changed with `scale`; use `width` or `height`, which keep the size of the symbols. The bounding box of the picture includes all nodes, including labels outside the chart.

5.5 Changing the white areas for colored backgrounds

If you draw colored areas in the chart with Ti*k*Z, the white areas behind the labels would stand out. For this case, the color of the cleared areas can be changed or switched off with two keys:

Key	Effect
`labelbg=<color>`	color of the box behind the label, of the strip between a dot and its label and of the field behind central vowels (default: the chart background `bg`)
`labelbg=off`	none of these three is drawn
`contour=<color>`	color of the contour around the label (default: the same color as `labelbg`; with `labelbg=off`, the chart background)
`contour=off`	no contour is drawn

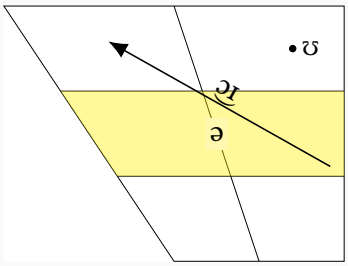
With `labelbg=off` (and `contour=off`), lines run through the label; this makes sense for labels that stand outside the lines or on areas where you take care of the clearing yourself.

The keys can be given on every level:

```
% for an individual label:
  \putvowel[l, labelbg=yellow]{e}{0}{1}
  \putcvowel[l, labelbg=yellow]{e}{2}
  \putipavowel[labelbg=yellow][e]{e}
  \putdiphthong[contour=off]{...}
  \putipadiphthong[contour=off]{...}
% for all following labels in a chart:
  \vowelchartlabels{labelbg=yellow}
% for all labels in a chart:
  \begin{vowelchart}[contour=off]
% for all charts:
  \usepackage{vowelchart}[labelbg=off]
  \vowelchartset{labelbg=yellow}
```

A setting for a single label overrides the settings of the higher levels. An empty value (`labelbg=`) restores the default.

```
\begin{vowelchart}[width=4.5cm, font=\large]
  \fill[yellow, opacity=.4] (vowel cs:h=0,v=1) -- (vowel
  ↪  cs:h=2,v=1) -- (vowel cs:h=2,v=2) -- (vowel cs:h=0,v=2)
  ↪  -- cycle;
  \putipavowel[labelbg=yellow!40!vowelchartbg][ə]{ə}
  \putdiphthong[contour=off]{ɔɪ̯}{1.9}{1.9}{0.5}{0.4}
  \putipavowel{ʊ}
\end{vowelchart}
```



Note that a translucent area (`opacity=.4`) produces a mixed color. To make the cleared areas match, use the mixture itself, as in the example: yellow at 40 % on the chart background is `yellow!40!vowelchartbg`.

6 Compatibility with `vowel` and `pst-vowel`

6.1 Moving from `(pst-)vowel` to `vowelchart`

The package `vowelchart` neither requires or changes `vowel` or `pst-vowel`. The environment is called `vowelchart` instead of `vowel`. The homonymous commands `\putvowel` and `\putcvowel` as well as the new commands `\putipavowel`, `\putdiphthong` and `\putipadiphthong` are defined *only inside* the `vowelchart` environment. In `vowel` environments the commands of `vowel` and `pst-vowel` keep working, so old and new charts can coexist in the same document.

For an overview of the differences between the three packages, see Table 4.

	`vowel`	`pst-vowel`	`vowelchart`
Output	built from boxes and tiny squares	= `vowel`	Ti*k*Z vector paths
Engines	any	LaTeX+dvips (PSTricks)	LuaLaTeX, XeLaTeX, pdfLaTeX
Size	`\vowelhunit`, `\vowelvunit`, font size	= `vowel`	`width=`, `height=`, font size (`\vowelhunit` and `\vowelvunit` still work for legacy charts)
Chart shapes	quadrangle, rectangle, triangle	= `vowel`	+ slanted, symmetric, freely defined corners
Grid options	plain, simple, standard, ipanew; three	= `vowel`	+ centralzone, centralcol (+ Ti*k*Z)
Vowel placement	`\putvowel` with absolute coordinates	= `vowel`	`\putvowel` with relative coordinates (and `\putvowel*` with absolute coordinates for legacy charts)
Cardinal vowels	`\putcvowel`$\{\ldots\}\{n\}$	= `vowel`	= `vowel`
IPA vowels	—	—	`\putipavowel` with Unicode or X-SAMPA input
Nodes	none	obligatory (PSTricks)	optional (Ti*k*Z)
Arrows	none	PSTricks	`\putdiphthong`, `\putipadiphthong`, Ti*k*Z

Table 4: Comparison of packages displaying vowel charts

The easy way. The *Vowel Chart Maker* (https://danielbuncic.github.io/vowelchart/) converts charts of `vowel` automatically: paste the code from `\begin{vowel}` to `\end{vowel}` into the *Maker*

(Ctrl+V or ⌘V on the page, or load it from a file). The *Maker* reads the shape and grid options, converts the absolute coordinates of every `\putvowel` into relative coordinates (a symbol that stands at its place in the IPA chart becomes a `\putipavowel`) and shows you the chart; you can then modify it if necessary and copy the LaTeX code of the new chart. The same works for `\putvowel*` in a `vowelchart`. The converted vowels are ordinary vowels of the new chart, so the output no longer contains any old-style commands. Node names of the old commands are kept, the standard arrows of `pst-vowel` (`\ncline`, `\ncarc` and `\nccurve` between two nodes, with `\naput`, `\nbput` or `\ncput` for the label) are converted into diphthong arrows between these nodes (Section 4.6), and the value of `nodesep` becomes the option `shorten` of the arrow. Curved arrows become straight, and other options of the arrows are not taken over. Other PSTricks commands cannot be converted.

By hand. If you prefer to transfer vowel charts created with `vowel` (with or without `pst-vowel`) to this package yourself, proceed in the following steps:

1. Rename the environment: `\begin{vowel}` → `\begin{vowelchart}`. The options `plain`, `simple`, `standard`, `ipanew`, `rectangle`, `triangle` and `three` keep their names.
2. `\putcvowel` needs no change, including the optional `[l]` and `[r]`.
3. `\putvowel` changes: the coordinates of the new command are no longer absolute lengths but relative coordinates, see Section 4.2. The easiest way to convert the coordinates is the *Vowel Chart Maker* (see above); you can also read the position off the old chart and estimate its relative position by eye, or use the formulas of Section 8.2. If you do not want to convert the coordinates at all, the legacy command `\putvowel*` (Section 6.2) accepts the old absolute coordinates unchanged.
4. The size of the chart is set with `width=` or `height=`. For compatibility, font size commands can still be used to change the chart's size, and the default width of `8em` equals `vowel`'s default of `2em` per unit. (`\vowelhunit` and `\vowelvunit` are also still understood, see Section 6.2.)
5. The options `noerase`, `t` and `b` are not supported. The chart can be aligned with `\raisebox`.
6. `vowel` allows different values for `\vowelhunit` and `\vowelvunit`, which distorts the chart. This is not supported. If both are set, `\vowelhunit` wins. (A distorted chart can be created by moving the corners, see Section 3.2.)

6.2 Legacy: absolute coordinates with `\putvowel*`

```
\putvowel*[l|r|x]{<symbol>}{<x>}{<y>}[<node name>]
```

This command exists only to make old charts work with a minimum of changes. It is not recommended for new charts. Use the relative coordinates of `\putvowel` (Section 4.2) or the IPA positions of `\putipavowel` (Section 4.4) instead.

With the star, `\putvowel*` takes the same absolute coordinates as in `vowel`: lengths measured from the top left corner of the default chart, with the y axis pointing downwards, usually multiples of `\vowelhunit` and `\vowelvunit`. A chart created with `vowel` can therefore be converted by renaming the environment and adding a star to every `\putvowel`. (Better still, let the *Vowel Chart Maker* convert the coordinates to relative ones, see Section 6.) If the chart was created with `pst-vowel`, the node name, which was the last obligatory argument there, must in addition be moved into square brackets:

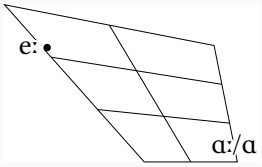
```
% vowel.sty
\putvowel[l]{ɛː/ɛ}{1.33\vowelhunit}{2\vowelvunit}
% vowelchart
\putvowel*[l]{ɛː/ɛ}{1.33\vowelhunit}{2\vowelvunit}

% pst-vowel.sty
\putvowel[l]{ɛː/ɛ}{1.33\vowelhunit}{2\vowelvunit}{Elongshort}
% vowelchart
\putvowel*[l]{ɛː/ɛ}{1.33\vowelhunit}{2\vowelvunit}[Elongshort]
```

The starred command `\putvowel*` accepts the same options as the normal `\putvowel` (Section 4.2), and the new options of `vowelchart` for changing size, colors, grid styles, etc., and for adding Ti*k*Z commands are available. Note, however, that the chart *shape* cannot be changed without the vowels placed with `\putvowel*` ending up in the wrong places. For technical reasons, the additional white field that clears the center line behind central vowels (see Section 7) is not drawn with `\putvowel*` (which is not a problem in most cases; where it is, just use the unstarred version to place the vowel instead.)

7 A known problem and some solutions

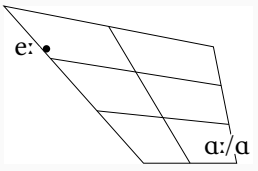
The space that the lines leave for vowel symbols written over them is created by white boxes and contours (or boxes and contours in the background color of the chart) drawn around the symbols, which are drawn after the lines and thus erase them. The size of these boxes and contours has been tweaked as much as possible to erase only those lines that should be erased. However, vowel symbols placed near diagonal lines can occasionally cause ugly missing bits in those diagonals, see the diagram below. (This is a problem that `vowel` sometimes had as well.)

```
\begin{vowelchart}[slanted] % with tricky labels
  \putvowel[l]{eː}{0.06}{0.8}
  \putvowel[x]{ɑː/ɑ}{2}{2.6}
\end{vowelchart}
```



To prevent this, you have three options. **First**, you can use `\hspace` or `\vspace` with positive or negative values within the label argument of `\putvowel` (e.g. `\putvowel[l]{\hspace{1.5pt}i}{0.1}{0.1}`) to move the label into a position where the problem does not occur; see the following diagram.

```
  \begin{vowelchart}[slanted] % corrected by moving the
  ↪  labels
  \putvowel[l]{\hspace{-1.1em}eː}{0.06}{0.8}
  \putvowel[x]{\hspace{-5pt}ɑː/ɑ}{2}{2.6}
\end{vowelchart}
```

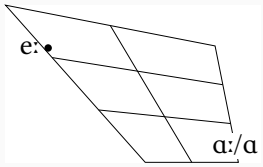


Second, you might want to tweak the size of the areas that are cleared for the labels. It can be changed with the options listed in Table 5. They are given like all other options (Section 3.1), i.e. after `\begin{vowelchart}` for a single chart, with `\vowelchartset` for all following charts, as a package option, or (except for `diphlabelpos`) in the options of a single vowel command, for example `\putvowel[l,pad=6pt]{e}{0.06}{0.8}` or `\putipavowel[pad=6pt][u]{u}`. An option given in a vowel command only applies to this vowel, so that you can make more space for one label without affecting any others. For `\putdiphthong` and `\putipadiphthong`, `diphmargin`, `labelbg`, and `contour` can be given in the Ti*k*Z options. Lengths given in `em` or `ex` refer to the font size of the chart, so the cleared areas grow and shrink together with the symbols.

Option	Default	Effect
`margin`	`0.06em`	Width of the contour around the glyphs. It clears the lines right at the outline of each symbol and is the main protection above and below the symbols.
`pad`	`0.10em`	The white box behind each symbol is this much wider than the symbol on each side.
`boxh`, `boxd`	`1ex`, `0pt`	Height above and depth below the baseline of this box. By default it reaches from the baseline to the x-height; the contour takes care of ascenders and descenders.
`gap`	`0.18em`	Distance between the symbol and the dot next to it (labels placed with `[l]` or `[r]`).
`lift`	`0.5ex`	The baseline of a label lies this far below the dot (or the position of a label placed with `[x]`).
`stripe`	`1.5pt`	Thickness of the white strip between a dot and its label that removes the piece of the horizontal line that would otherwise remain there.
`zonew`, `zoneh`	`0.7em`, `1em`	Size of the white field that is drawn behind central vowels (see below). The field also covers a piece of any horizontal line close to the vowel; for a vowel at the very top or bottom of the chart (e.g. `\putcvowel[x]` at position 9), choose a smaller `zoneh`, or switch the field off with `zoneh=0pt`.
`labelbg`	`bg`	Color of the white box and of the strip behind the labels. `labelbg=off` switches the box off (Section 5.5).
`contour`	as `labelbg`	Color of the contour around the glyphs. `contour=off` switches the contour off (Section 5.5).
`diphmargin`	`0.15em`	Width of the contour around the label of a diphthong arrow.

Table 5: Variables determining the white space around vowel labels

```
\begin{vowelchart}[slanted] % with adjusted options
  \putvowel[l, labelbg=off, contour=off]{eː}{0.06}{0.8}
  \putvowel[x, boxh=.7em, boxd=2pt]{aː/ɑ}{2}{2.6}
\end{vowelchart}
```



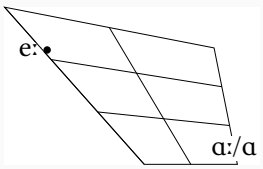
Remedies for typical problems:

- A line runs too close to a symbol, or remains between the parts of a symbol such as "(i̯)": Increase `pad`. Increase `margin` if the line touches the outline of the glyph.
- A diagonal line has a notch next to a symbol: The white box or the contour is too large for this position. Decrease `pad` and, if necessary, `margin`, or move the label with `\hspace` as described above. This happens most often in strongly slanted shapes.
- Descenders cut into a diagonal line, or a line runs through the descender: A positive `boxd` (e.g. `0.2ex`) clears the area below the baseline but also removes more of the line there.
- A bit of a horizontal line remains between a dot and its label, especially in slanted charts: Increase `stripe`. In slanted vowel charts the horizontal lines are slightly tilted, so a thicker strip is needed. Do not choose a thickness larger than necessary, because it also removes parts of neighboring lines.
- The label sits too close to or too far from its dot: Change `gap`.
- All labels sit too high or too low relative to their dots: Change `lift`.
- The central vowels ([ə], [ɐ], and central [a], and more generally any symbol placed with `[x]` at `h=1`) stand on the center line, which is nearly vertical and runs through the symbol. To keep the

line away from them, a white rectangle of size `zonew` × `zoneh` is drawn in the background color, centered on the position of the symbol, before the symbol is set. Increase `zonew` if a piece of the center line remains left or right of the symbol, and decrease `zoneh` if the rectangle removes too much of a horizontal line near the symbol. With `zoneh=0pt` the field is switched off. It is not drawn for symbols placed next to a dot (`[l]`, `[r]`) or for empty symbols.

Third, you can add Ti*k*Z commands, e.g. to draw a white rectangle over a line to make more space for a vowel label or to redraw a line that should not have been erased, as in the following example.

```
% With corrections using TikZ
\begin{vowelchart}[slanted]
  \putvowel[l]{eː}{0.06}{0.8}
  % Redraw line AFTER adding the vowel label for [eː]:
  \draw[line width=\vowelchartline] (vowel cs:h=0,v=0) --
  ↪  (vowel cs:h=0,v=3);
  % Make space BEFORE adding the vowel label for [aː/a]:
  \fill[vowelchartbg] (vowel cs:h=1.75,v=2.3) rectangle
  ↪  (vowel cs:h=2.25,v=2.9);
  \putvowel[x]{aː/a}{2}{2.6}
\end{vowelchart}
```



8 The mathematics behind it

This chapter is not needed to use the package. The formulas given below are only useful if (a) you want to know exactly what `\putvowel` does with its arguments (8.1), or (b) you want to know how old absolute coordinates of `vowel` are converted into the new relative coordinates (8.2).

8.1 How `vowelchart` turns relative into real coordinates

A chart is defined by four corners P_{tl}, P_{tr}, P_{bl} and P_{br} (top left, top right, bottom left, bottom right; see Section 3.2). Each corner is a pair (x, y), where y increases *downwards*. A position in the chart is given by the relative coordinates $h \in [0, 2]$ (from left to right) and $v \in [0, 3]$ (from top to bottom). For the calculation, it is more convenient to express both as fractions of the way across the chart. We call them s and t:

$$s = \frac{h}{2}, \qquad t = \frac{v}{3}.$$

So s is 0 at the left edge and 1 at the right edge, and t is 0 at the top edge and 1 at the bottom edge. A point with $h = 0.5$ and $v = 1$, for example, has $s = 0.25$ and $t = \frac{1}{3}$: it lies a quarter of the way from the left to the right and a third of the way from the top to the bottom.

The package then works in two steps. First, it determines the two points on the left and on the right edge of the chart at the height v, namely the points that are the fraction t of the way from the top corner to the bottom corner:

$$L = P_{\text{tl}} + t\,(P_{\text{bl}} - P_{\text{tl}}), \qquad R = P_{\text{tr}} + t\,(P_{\text{br}} - P_{\text{tr}}).$$

Second, it goes the fraction s of the way from L to R: $P = L + s\,(R - L)$. Written as one formula, this is

$$P(h, v) = (1 - s)(1 - t)\,P_{\text{tl}} + s(1 - t)\,P_{\text{tr}} + (1 - s)\,t\,P_{\text{bl}} + s\,t\,P_{\text{br}}.$$

Each corner is weighted by how close the point is to it. This is a bilinear interpolation between the four corners. This formula is used for all shapes, for the coordinate system `vowel cs` (Section 5.2) and for all vowel placement commands.

The corners are given in the unit of the chart. Its length u is derived from the option `width` or `height` (Section 3) and the extent of the four corners:

$$u = \frac{\text{width}}{x_{\max} - x_{\min}} \qquad \text{or} \qquad u = \frac{\text{height}}{y_{\max} - y_{\min}},$$

where $x_{\max}$, $x_{\min}$, $y_{\max}$, and $y_{\min}$ are the largest and smallest x and y values of the four corners. The point $P = (X, Y)$ is drawn at the Ti*k*Z position $(u \cdot X,\ -u \cdot Y)$; the minus sign is needed because Ti*k*Z's y axis points upwards.

Example. For the default shape `normal`, the corners are $(0, 0)$, $(4, 0)$, $(2, 3)$ and $(4, 3)$, so that

$$X = \frac{2v}{3} + 2h - \frac{hv}{3}, \qquad Y = v.$$

The vowel at $h = 0.5$, $v = 1$ is therefore at $X = \frac{2}{3} + 1 - \frac{1}{6} = 1.5$ and $Y = 1$. In a chart with `width=4cm` this is $u = 1$ cm, i.e. 1.5 cm to the right of and 1 cm below the top left corner.

8.2 From absolute `vowel` coordinates to relative `vowelchart` coordinates

In most cases, you do not have to do this by hand: the *Vowel Chart Maker* (https://danielbuncic.github.io/vowelchart/) converts the coordinates of old charts automatically, using exactly the formulas given here (Section 6).

In `vowel`, the position of a vowel is a pair of lengths (x, y), measured from the top left corner of the chart. To convert such a pair to the relative coordinates (h, v) of `\putvowel`, divide both lengths by the units of the old chart:

$$a = \frac{x}{\texttt{\textbackslash vowelhunit}}, \qquad b = \frac{y}{\texttt{\textbackslash vowelvunit}}.$$

If the old code gave the coordinates in multiples of the units (such as `1.5\vowelhunit` and `1\vowelvunit`), a and b are simply these numbers (here $a = 1.5$ and $b = 1$). The new coordinates are then:

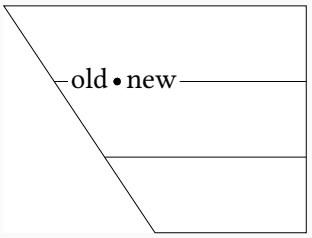
	four heights (default)	`three`
v for all shapes	b	$1.5\,b$
h for `normal`	$\dfrac{3a - 2b}{6 - b}$	$\dfrac{2a - 2b}{4 - b}$
h for `rectangle`	$\dfrac{a}{2}$	$\dfrac{a}{2}$
h for `triangle`	$\dfrac{3a - 2b}{6 - 2b}$	$\dfrac{a - b}{2 - b}$

The formulas for `three` differ because `vowel` draws such a chart only two units of `\vowelvunit` high (and uses a correspondingly larger unit), so that the overall height stays the same. For the triangle, the formulas are undefined at the apex (the bottom of the chart), where every h describes the same point; set $h = 1$ in this case.

The formulas also describe the position correctly if the new chart is larger or smaller than the old one, because h and v only state where a point lies *within* the quadrilateral. But note that the new chart always keeps the proportions of its shape, whereas `vowel` allowed `\vowelhunit` and `\vowelvunit` to be set independently of each other. (If you want to reproduce this effect, you have to adjust the corners of the chart; see Section 3.2.)

Check. In a chart with four heights, the point $a = 1.5$, $b = 1$ gives $v = 1$ and, for the shape `normal`, $h = \frac{4.5-2}{5} = 0.5$. The following chart draws this point twice, once with the legacy command `\putvowel*` (Section 6.2) with absolute coordinates and once with `\putvowel` (Section 4.2) with relative coordinates; the two dots coincide:

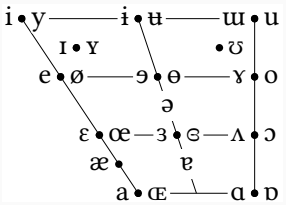
```
\begin{vowelchart}[width=4cm, simple]
  \putvowel*[l]{old}{1.5\vowelhunit}{1\vowelvunit}
  \putvowel[r]{new}{0.5}{1}
\end{vowelchart}
```



9 Examples

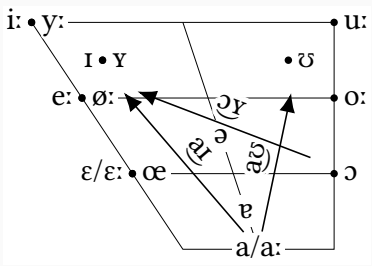
Full IPA vowel chart

```
\begin{vowelchart}
  \putipavowel{i} \putipavowel{y} \putipavowel{1}
  \putipavowel{u-} \putipavowel{M} \putipavowel{u}
  \putipavowel{I} \putipavowel{Y} \putipavowel{U}
  \putipavowel{e} \putipavowel{2} \putipavowel{@-}
  \putipavowel{8} \putipavowel{7} \putipavowel{o}
  \putipavowel{@} \putipavowel{E} \putipavowel{9}
  \putipavowel{3} \putipavowel{3-} \putipavowel{V}
  \putipavowel{O} \putipavowel{ae} \putipavowel{6}
  \putipavowel{a} \putipavowel{OE} \putipavowel{A}
  \putipavowel{Q}
\end{vowelchart}
```



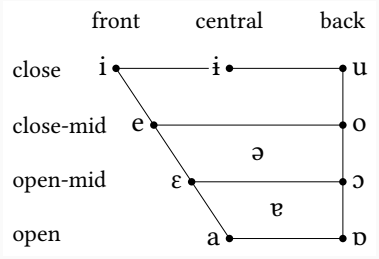
Standard German monophthongs and diphthongs

```
\begin{vowelchart}[width=4cm]
  \large
  \putipavowel[i:]{i} \putipavowel[y:]{y} \putipavowel[u:]{u}
  \putipavowel{I} \putipavowel{Y} \putipavowel{U}
  \putipavowel[e:]{e} \putipavowel[ø:]{ø} \putipavowel[o:]{o}
  \putipavowel[ɛ/ɛ:]{ɛ} \putipavowel{œ} \putipavowel{O}
  \putipavowel{@} \putipavowel{6}
  \putipavowel[a/a:]{'a'}
  \putdiphthong{ɔʏ}{1.8}{1.8}{0.45}{0.9}
  \putdiphthong{aʊ}{1.1}{2.8}{1.67}{0.9}
  \putdiphthong{aɪ}{0.9}{2.8}{0.35}{0.9}
\end{vowelchart}
```



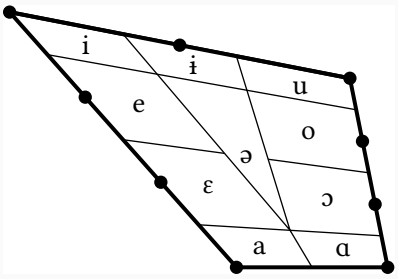
A chart with labels on the axes

```
\begin{vowelchart}[width=3cm, simple]
  \begin{scope}[font=\footnotesize]
    \node[anchor=south, yshift=4mm] at (vowel cs:h=0, v=0)
    ↪  {front};
    \node[anchor=south, yshift=4mm] at (vowel cs:h=1, v=0)
    ↪  {central};
    \node[anchor=south, yshift=4mm] at (vowel cs:h=2, v=0)
    ↪  {back};
    \node[anchor=west] at (-2, 0) {close};
    \node[anchor=west] at (-2, -1) {close-mid};
    \node[anchor=west] at (-2, -2) {open-mid};
    \node[anchor=west] at (-2, -3) {open};
  \end{scope}
  \putipavowel{i} \putipavowel{ɨ} \putipavowel{u}
  \putipavowel{e} \putipavowel{o} \putipavowel{ə}
  \putipavowel{ɛ} \putipavowel{ɔ} \putipavowel{ɐ}
  \putipavowel{a} \putipavowel{ɒ}
\end{vowelchart}
```



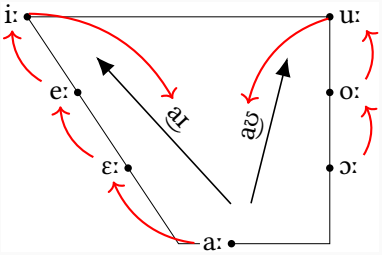
Vowel quadrilateral according to Daniel Jones with ten cardinal vowel zones

```
\begin{vowelchart}[slanted, plain, linewidth=1.5pt,
↪  dotsize=2.5pt, width=5cm]
  % Draw internal lines; the triangle erases the line drawn
  ↪  previously
  \draw[line width=0.5pt] (vowel cs:h=0, v=1.5) -- (vowel
  ↪  cs:h=2, v=1.5);
  \draw[line width=0.5pt, fill=vowelchartbg] (vowel
  ↪  cs:h=0.667, v=0) -- (vowel cs:h=1, v=2.5) -- (vowel
  ↪  cs:h=1.333, v=0) -- cycle;
  \draw[line width=0.5pt] (vowel cs:h=0, v=0.5) -- (vowel
  ↪  cs:h=2, v=0.5);
  \draw[line width=0.5pt] (vowel cs:h=0, v=2.5) -- (vowel
  ↪  cs:h=2, v=2.5);
  \draw[line width=0.5pt] (vowel cs:h=1, v=2.5) -- (vowel
  ↪  cs:h=1, v=3);
  % Place vowel symbols in the middle of the zones
  \putvowel{i}{0.333}{0.3} \putvowel{u}{1.667}{0.3}
  \putvowel{e}{0.388}{1} \putvowel{o}{1.611}{1}
  \putvowel{ɛ}{0.444}{2} \putvowel{ɔ}{1.556}{2}
  \putvowel{a}{0.5}{2.75} \putvowel{ɑ}{1.5}{2.75}
  \putvowel{ɨ}{1.001}{0.3} \putvowel{ə}{1.001}{1.5}
  % Place dots for cardinal vowels 1 to 9
  \putcvowel[x]{}{1} \putcvowel[x]{}{2} \putcvowel[x]{}{3}
  ↪  \putcvowel[x]{}{4} \putcvowel[x]{}{5}
  ↪  \putcvowel[x]{}{6} \putcvowel[x]{}{7}
  ↪  \putcvowel[x]{}{8} \putcvowel[x]{}{9}
  % Redraw top outer line
  \draw[line width=\vowelchartline] (vowel cs:h=0, v=0) --
  ↪  (vowel cs:h=2, v=0);
\end{vowelchart}
```



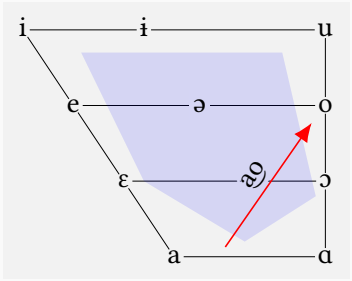
The Great Vowel Shift

```
\begin{vowelchart}[width=4cm, plain]
  \tikzset{GVC/.style={red, thick, ->, shorten >=2pt, shorten
  ↪  <=2pt}}
  \putvowel[l]{aː}{0.7}{3}[a] \putipavowel[ɛː]{ɛ}[E]
  \putipavowel[eː]{e}[e] \putipavowel[iː]{i}[i]
  \putdiphthong{aɪ̯}{0.9}{2.5}{0.3}{0.5}[ai]
  \putipavowel[ɔː]{ɔ}[O] \putipavowel[oː]{o}[o]
  \putipavowel[uː]{u}[u]
  \putdiphthong{aʊ̯}{1.1}{2.5}{1.7}{0.5}[au]
  \draw[GVC] (a.west) to[bend left=30] (E.south);
  \draw[GVC] (E.north west) to[bend left=30] (e.south);
  \draw[GVC] (e.north west) to[bend left=30] (i.south);
  \draw[GVC] (i.east) to[bend left=30] (ai.north west);
  \draw[GVC] (O.north east) to[bend right=30] (o.south east);
  \draw[GVC] (o.north east) to[bend right=30] (u.south east);
  \draw[GVC] (u.west) to[bend right=30] (au.north east);
\end{vowelchart}
```



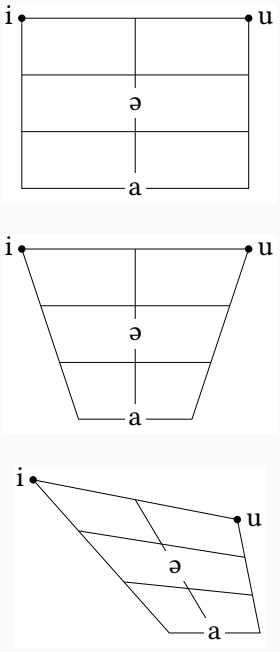
Shaded vowel space

```
\begin{vowelchart}[width=4cm, simple, bg=black!5!white,
↪  bgmargin=5pt]
  \putcvowel{i}{1} \putcvowel{e}{2} \putcvowel{ɛ}{3}
  ↪  \putcvowel{a}{4}
  \putcvowel{ɑ}{5} \putcvowel{ɔ}{6} \putcvowel{o}{7}
  ↪  \putcvowel{u}{8}
  \fill[blue, opacity=.12]
  (vowel cs:h=0.3,v=0.3) -- (vowel cs:h=1.7,v=0.3) -- (vowel
  ↪  cs:h=1.9,v=2.2)
  -- (vowel cs:h=1,v=2.8) -- (vowel cs:h=0.2,v=2) -- cycle;
  {\vowelchartlabels{contour=blue!12!vowelchartbg,
  ↪  labelbg=blue!12!vowelchartbg}
    \putvowel{ə}{1}{1}
    \putdiphthong[red]{ao}{0.7}{2.9}{1.9}{1.2}
  }
  \putvowel[x]{ɨ}{0.8}{0}
\end{vowelchart}
```



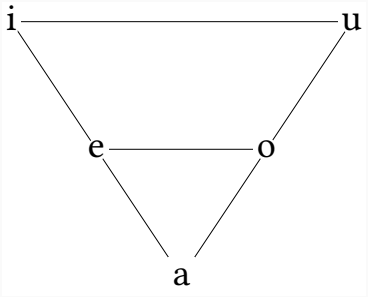
The same vowels in different shapes

```
\def\demo#1{%
  \begin{vowelchart}[#1, width=3cm]
    \putipavowel{i}
    \putipavowel{u}
    \putipavowel{'a'}
    \putipavowel{ə}
  \end{vowelchart}%
}
\demo{rectangle}\\[1em]
\demo{symmetric}\\[1em]
\demo{slanted}
```



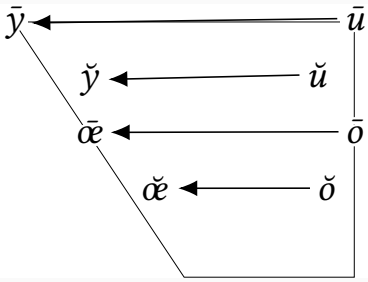
A three-height system on a triangular chart

```
\begin{vowelchart}[triangle, simple, three, width=4.5cm,
↪  font=\Large]
  \putvowel{i}{0}{0}   \putvowel{u}{2}{0}
  \putvowel{e}{0}{1.5} \putvowel{o}{2}{1.5}
  \putvowel{a}{1}{3}
\end{vowelchart}
```

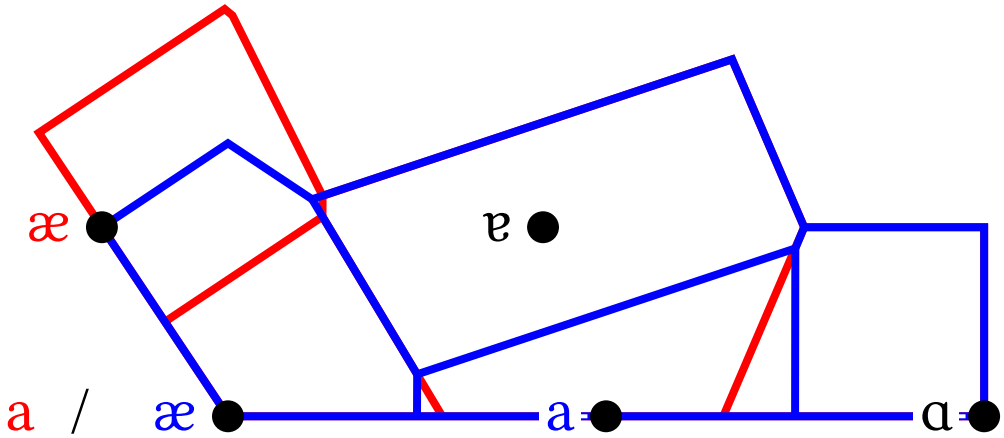


Diphthong arrows used for illustrating sound change

```
\begin{vowelchart}[plain, width=4.5cm, font=\Large]
  \putvowel[x]{\textit{ū}}{2}{0}[ulong]
  \putvowel[x]{\textit{ŭ}}{1.75}{0.67}[ushort]
  \putvowel[x]{\textit{ō}}{2}{1.33}[olong]
  \putvowel[x]{\textit{ŏ}}{1.75}{2}[oshort]
  \putvowel[x]{\textit{ȳ}}{0}{0}[ylong]
  \putvowel[x]{\textit{y̆}}{0.25}{0.67}[yshort]
  \putvowel[x]{\textit{œ̄}}{0}{1.33}[oelong]
  \putvowel[x]{\textit{œ̆}}{0.25}{2}[oeshort]
  \putipadiphthong{}{(ulong.west)}{(ylong.east)}
  \putipadiphthong{}{(ushort.west)}{(yshort.east)}
  \putipadiphthong{}{(olong.west)}{(oelong.east)}
  \putipadiphthong{}{(oshort.west)}{(oeshort.east)}
\end{vowelchart}
```



9.1 Test



Appendix: Short reference of commands and options

Syntax

```
\usepackage[<options>]{vowelchart}
\vowelchartset{<options>}
\vowelchartlabels{<label options>}

\begin{vowelchart}[<options>]
         \putvowel[<vowel options>]{<label>}{<h>}{<v>}[<node name>]
        \putvowel*[<vowel options>]{<label>}{<x>}{<y>}[<node name>]
        \putcvowel[<vowel options>]{<label>}{<number>}[<node name>]
      \putipavowel[<vowel options>][<label>]{<symbol>}[<node name>]
     \putdiphthong[<TikZ options>] {<label>}{<h1>}{<v1>}{<h2>}{<v2>}[<node name>]
  \putipadiphthong[<TikZ options>] {<label>}{<start>}{<end>}[<node name>]
\end{vowelchart}
```

The arguments in square brackets are optional.

- `<options>` are the chart options of the table below. `\vowelchartset` and the package options set defaults for all charts; options in the environment apply to one chart (Section 3.1).
- `<vowel options>` are `l`, `r` or `x` (position of the label relative to the dot) and all options marked *vowel* in the last column of the table. They apply to this vowel only.
- `\putipavowel` has two optional arguments before the symbol. If only one is given, it is the `<label>`; with two, the first one holds the `<vowel options>` and the second one the `<label>` (which can be empty for a dot without label).
- `<label options>` are `labelbg=` and `contour=`; they are set for the labels that follow, up to the end of the current group (Section 5.5).
- `<h>`, `<v>` are relative coordinates ($0 \ldots 2$ and $0 \ldots 3$, Section 4.2), `<x>`, `<y>` are lengths (legacy, Section 6.2), `<number>` is the number of a cardinal vowel (1–16, Section 4.3), `<symbol>` an IPA or X-SAMPA vowel symbol (Table 3).
- `<start>` and `<end>` are IPA symbols or Ti*k*Z coordinates in parentheses, such as `(vowel cs:h=1,v=2)` or `(name.west)` (Section 4.6).
- `<TikZ options>` are passed to the arrow; the options `labelbg=`, `contour=`, `diphmargin=` and `diphlabelpos=` can be given there as well.

Options

All options can be given for a single chart, with `\vowelchartset` or as package options (Section 3.1). The column *Single* shows which options can also be given in the options of an individual command: *vowel* stands for the vowel commands (`\put…vowel`) and *diphthong* for `\putdiphthong` and `\putipadiphthong` (in their Ti*k*Z options). An option marked — has to be set at least for the whole chart.

Option	Default	Effect	Command	Section
Shape				
`normal`, `rectangle`, `triangle`, `symmetric`, `slanted`	`normal`	predefined shapes (set all four corners)	—	3.2
`tl={x,y}`, `tr`, `bl`, `br`	from shape	individual corners	—	3.2
Grid lines, dots, and arrows				
`plain`, `simple`, `ipanew`, `centralzone`, `standard`, `centralcol`, `none`	`ipanew`	line patterns	—	3.3
`three`, `four`	`four`	number of heights	—	3.3
`linewidth=`⟨dim⟩	`0.2pt`	grid line width	—	3.7
`dotsize=`⟨dim⟩	`1.4pt`	vowel dot radius	—	3.7
`arrowwidth=`⟨dim⟩	`0.6pt`	diphthong line width	—	3.7
`arrowhead=`⟨dim⟩	`6pt`	size of diphthong arrowhead	—	3.7
Size				
`width=`⟨dim⟩	`8em`	exact width of the quadrilateral	—	3.4
`height=`⟨dim⟩	—	exact height of the quadrilateral	—	3.4
⟨dim⟩	—	shorthand for `width`	—	3.4
Colors				
`fg=`⟨color⟩	text color	foreground color	—	3.5
`bg=`⟨color⟩	`white`	background color	—	3.5
`bgmargin=`⟨dim⟩	`0pt`	margin of the background around the chart	—	3.5
`labelbg=`⟨color|off⟩	`bg`	color of areas cleared behind vowel labels	vowel, diphthong	5.5
`contour=`⟨color|off⟩	as `labelbg`	color of contour around labels	vowel, diphthong	5.5
Font				
`font=`⟨commands⟩	—	font commands for the chart	—	3.6
`fontsize=`⟨dim⟩	—	fixed font size	—	3.6
Position of a label (only in the options of a vowel command)				
`l`, `r`, `x`	`x`	label left of, right of, or centered on the dot	*only* vowel	4.1
White areas around labels				
`margin=`⟨dim⟩	`0.06em`	width of the contour	vowel	7
`pad=`⟨dim⟩	`0.10em`	extra width of the white box	vowel	7
`boxh=`, `boxd=`	`1ex`, `0pt`	height and depth of the white box	vowel	7
`gap=`⟨dim⟩	`0.18em`	distance between label and dot	vowel	7
`lift=`⟨dim⟩	`0.5ex`	baseline lower than dot	vowel	7
`stripe=`⟨dim⟩	`1.5pt`	thickness of the strip next to dots	vowel	7
`zonew=`, `zoneh=`	`0.7em`, `1em`	size of field behind central vowels	vowel	7
Diphthongs				
`diphmargin=`⟨dim⟩	`0.15em`	width of the contour around diphthong labels	diphthong	7
`diphlabelpos=`⟨above|below|on⟩	`above`	position of diphthong labels	diphthong	4.5
`ipashorten=`⟨dim⟩	`3pt`	arrows shortened at IPA positions	—	4.6

Version history

1.1	23 Nov 2026	developed the *Vowel Chart Maker* to make creating and converting vowel charts easier • new options `bgmargin` (to add a margin), `none` (for a completely invisible grid), `arrowwidth` and `arrowhead` (for the line width and the heads of diphthong arrows) • the area of the chart without a `bgmargin` now ends at its outermost elements (before: the dot of *i* could stick out of the chart, which is why margins of 0.7 em above and below and 2 pt left and right were added) • diphthong arrows are now drawn with the arrowhead `-Latex` and are thicker by default • diphthong label now reacts to `contour=`
1.0	21 Nov 2026	first published version