

Pheatures Speadsheet: User's Manual

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Contents

1.	Overview	2
2.	Downloading and installing the program	2
3.	Some background on features	2
3.1	<i>Features and feature matrices</i>	2
3.2	<i>Phoneme inventories</i>	3
4.	Getting started: a quick guide	3
5.	The Pheatures Spreadsheet user interface in detail	5
5.1	<i>Open a phoneme inventory</i>	5
5.2	<i>Selecting natural classes: Spreadsheet view</i>	6
5.3	<i>Chart view</i>	7
5.4	<i>Entering a feature change</i>	9
5.5	<i>Entering features using the keyboard</i>	10
5.6	<i>Extracting feature lists to the clipboard</i>	11
6.	Feedback and warnings	11
6.1	<i>Redundant features</i>	11
6.2	<i>Contradictions</i>	12
6.3	<i>Missing symbols</i>	12
6.3.1	<i>What to do when you get a question mark?</i>	13
6.3.2	<i>An example of how to deal with question marks</i>	13
7.	The phoneme inventory editor	15
8.	Listing all the natural classes of a language	17
9.	Customizing the feature system	17
10.	Credits	18
10.1	<i>People</i>	18
10.2	<i>Fonts and software resources employed by Pheatures Spreadsheet</i>	18

1. Overview

Pheatures Spreadsheet is a kind of calculating system for features. If you use it correctly, then you can provide feature specifications that describe natural classes correctly and also carry out the correct featural changes for any rule.

The program is also meant to teach you features. Specifically, it doesn't tell you the answer, but checks answers that you enter in. Sometime it helps by pointing out problems with the answer you entered.

This manual explains how to use the program.

2. Downloading and installing the program

Pheatures Spreadsheet is a Java program and should run on the most common operating systems: Windows, Mac, and Linux.

Download Pheatures Spreadsheet from its current web home, <http://www.linguistics.ucla.edu/people/hayes/120A/Pheatures/>.

You will get a zipped folder of files, which you should unzip in some location you will remember. Within the folder is the program itself, called **Pheatures.jar**. Click on it and it will probably run; it is compatible with both Windows and Mac. It also includes the needed phonetic font.

The only reason the program is likely to not run is if you don't have the so-called "Java Runtime Environment" on your machine. This is already installed on most computers, but if you don't have it you can get it for free. Currently (January 2021) you can get it here: <https://www.java.com/en/download/manual.jsp>. If that doesn't work, search the web for "Java Runtime Environment" to get to the right page. Then download and install it.

If you have installation problems using a Mac, visit <https://linguistics.ucla.edu/people/hayes/120a/Pheatures/> and download the Mac manual there, which will explain what to do.

3. Some background on features

3.1 Features and feature matrices

Pheatures Spreadsheet follows classical phonological theory in assuming that a sound is represented simply a bundle of features and their values, like this:

$$\left[\begin{array}{l} -\text{syllabic} \\ -\text{sonorant} \\ -\text{continuant} \\ -\text{delayed release} \\ +\text{labial} \\ -\text{labiodental} \\ -\text{voice} \\ \text{etc.} \end{array} \right] = [p]$$

Such a bundle is often called a **feature matrix**. In a formalized phonological system, the IPA symbol is only a convenient label for the matrix itself. In expressing feature matrices we can also omit certain features, and typically when we do this the result will stand not just for one sound but for a whole set of sounds: thus, [+syllabic], a matrix with just one feature, will designate the set of all vowels in a language.

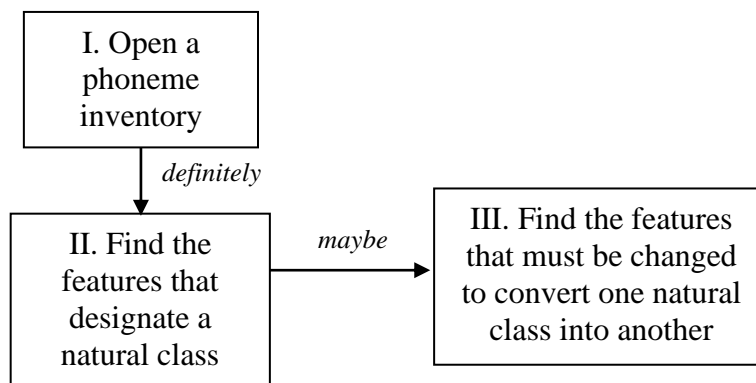
The features that come with Pheatures Spreadsheet are the ones given in Bruce Hayes's text *Introductory Phonology* (Blackwell-Wiley, 2009). However, it would be possible to have the program work with a different set of features; see section 9 below. The phonetic symbols are the standard symbols of the International Phonetic Alphabet, using the Unicode font Doulos SIL. There are about two hundred base symbols and eighteen diacritics.

3.2 Phoneme inventories

When we work with features, we usually have a particular language in mind. In fact, it is essential to have a particular language in mind, because the set of sounds that a feature matrix designates (i.e. the “natural class” it denotes) depends on the phoneme inventory of the language. [p t k] is a natural class in English (namely [–delayed release, –voice], the voiceless non-affricated stops), but it is not a natural class in Persian, because Persian has an additional voiceless non-affricated stop, namely [q]. So, the first thing you do when using Pheatures Spreadsheet is to pick an existing phoneme inventory, or make a new one for a new language you're working on.

4. Getting started: a quick guide

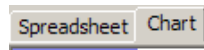
The standard way to use the program is:



I. Open and view a phoneme inventory

Click on the **File** menu, then **Open phoneme inventory**. Pick what you want. Or see section 7 for how to make a new inventory.

On the tabs in the middle of the screen, click **Spreadsheet** or **Chart** according to your preference.



The German phoneme inventory provided with the program will look like this as a chart:

Spreadsheet		Chart					
p		t		k			
b		d		g			
	p̥f	ts					
	f	s	ʃ	ç	x		h
	v	z				ʁ	
m		n			ŋ		
				j			
		l					
i:	y:		u:				
ɪ	ʏ		ʊ				
e:	ø:		o:				
ɛ	œ		ɔ				
		ɑ					
		ɑ:					

It will look like this viewed as a spreadsheet (only a bit of it is shown here):

Spreadsheet		Chart							
		syll...	stress	long	con...	son...	con...	del...	ap...
	p	-	-	-	+	-	-	-	-
	t	-	-	-	+	-	-	-	-
	k	-	-	-	+	-	-	-	-
	b	-	-	-	+	-	-	-	-
	d	-	-	-	+	-	-	-	-
	g	-	-	-	+	-	-	-	-
	p ^f	-	-	-	+	-	-	+	-
	ts	-	-	-	+	-	-	+	-

II. Find the features that designate a natural class.

On the window at the top of the screen labeled **Select some sounds by their features:**

click features and pluses and minuses until exactly the natural class you want is highlighted on the screen.

The program will show you the set of sounds designated by these feature values.

III. Find the features that must be changed to convert one natural class into another.

(This is needed to formalize phonological rules.) First find the natural class on the “left side of the arrow”, as in II immediately above. Then, in the window labeled ...**and change them into these features:**

pick some features and values, just as you did in the selection window. The program will show you the changes with arrows.

5. The Pheatures Spreadsheet user interface in detail

5.1 Open a phoneme inventory

When you open the program, you will not see much yet; you have to open or create a phoneme inventory first. Usually, if you are using the program for the first time, your teacher will give you a phoneme inventory or specify one of the inventories that comes with the program. You can access these existing inventories by clicking **File** then **Open phoneme inventory**. The screen will then be populated with the phonemes of the inventory you selected.

If you want to make a new inventory, select **File, New phoneme inventory**, then follow the directions in section 7 below.

5.2 Selecting natural classes: Spreadsheet view

There are two ways of viewing the phoneme inventory. You can switch between them at any time. Look at the mid-left part of the screen and click on the tabs for either **Spreadsheet** or **Chart**.

The spreadsheet view will serve to show you the features of each of the sounds that you have selected. The sounds appear in a list and the columns represent the values the sound has for each of the features. The sounds below are from the file HypotheticalLanguage.inv.

	sylla...	stress	long	con...	son...	cont...	del...	app...	tap	trill	nasal	voice	spre...	con...	labial	round
p	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-
t	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
k̟	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
k	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
q	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
ʔ	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-
ts̺	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-
f	-	-	-	+	-	+	+	-	-	-	-	-	-	-	+	-
s	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-
ʃ	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-
x̟	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-

You can restrict the features in this list by choosing some feature values in the selection panel, labeled **Select some sounds by their features**. You will see that the list is updated to contain only the sounds that have these features. So, if you select [+labial], like this:

Select some sounds by their features:

+

▼

labial

▼

you will get this (interface not completely shown):

Spreadsheet		Chart														
		syll...	stress	long	con...	son...	con...	del...	ap...	tap	trill	nasal	voice	spr...	con...	labia
p		-	-	-	+	-	-	-	-	-	-	-	-	-	-	+
f		-	-	-	+	-	+	+	-	-	-	-	-	-	-	+
m		-	-	-	+	+	-		-	-	-	+	+	-	-	+
w		-	-	-	-	+	+		+	-	-	-	+	-	-	+
y		+	-	-	-	+	+		+	-	-	-	+	-	-	+
u		+	-	-	-	+	+		+	-	-	-	+	-	-	+
ø		+	-	-	-	+	+		+	-	-	-	+	-	-	+
o		+	-	-	-	+	+		+	-	-	-	+	-	-	+
œ		+	-	-	-	+	+		+	-	-	-	+	-	-	+
ɒ		+	-	-	-	+	+		+	-	-	-	+	-	-	+

5.3 Chart view

The chart view shows where the sounds in the inventory would end up in an IPA chart. That is, the consonants are given on top and the vowels below. The sounds of these two are then ordered in the usual way, by place of articulation (columns) and manner (rows). As in the spreadsheet view, you can use the selection panel to restrict to a particular natural class of sounds, but contrary to the spreadsheet view, the symbols that are distinct from your selection will not disappear but will be grayed out.

You can do the same thing in the chart view as in the spreadsheet view, but you get to see different things. Here is the chart view of the HypotheticalLanguage.inv phoneme inventory:

5.4 Entering a feature change

Suppose you are trying to write a phonological rule. Typically, the rule will apply to some natural class of segment, place on the left side of the arrow. Then, you change some features to characterize what the rule does. Example: suppose in Hypothetical Language, all non-low vowels are rounded before [w]. We can get the non-low vowels with [+syllabic, -low]:

Select some sounds by their features: clear keyboard

+	▼	syllabic	▼
-	▼	low	▼

Spreadsheet Chart									
p		t			k	q		ʔ	
					k̚				
		ts							
	f	s	ʃ		x	ç	ħ	h	
					x̚				
m		n	ɳ		ŋ	ɴ			
					ŋ̚				
		r							
				j					
		l							
w									
i	y	ɯ	u						
e	ø	ɤ	o						
æ	œ	ɑ	ɒ						

We can then make these vowels all [+high] by visiting the change window:

... and change them into these features: clear keyboard

+	▼	high	▼
---	---	------	---

The relevant part of the screen will look like this:

i → i	y → y	ɯ → ɯ	u → u
e → i	ø → y	ɤ → ɯ	o → u
æ	œ	ɑ	ɒ

You can see that all nonlow vowels have been rendered [+high]. Indeed, the *high* vowels were rendered [+high] as well but that didn't make any difference (vacuous change).

The same thing can be done in the spreadsheet window, which will look (in the relevant place) like this:

Spreadsheet		Chart		
		sylla...	stress	long
i	→ i	+	-	-
y	→ y	+	-	-
ɯ	→ ɯ	+	-	-
u	→ u	+	-	-
e	→ i	+	-	-
ø	→ y	+	-	-
ɤ	→ ɯ	+	-	-
o	→ u	+	-	-

Sometimes there is no phonetic symbol that can depict the sound you created by performing a change, and Pheatures Spreadsheet displays a question mark instead. As you are working with this interface, you will notice that the back-ground of this table occasionally turns yellow or red.¹ This is a signal that something is the matter with the features that you have selected, and this will be discussed in section 6.

5.5 Entering features using the keyboard

You can operate Pheatures Spreadsheet faster by using the keyboard instead of the mouse to enter your features. This works either for selecting a natural class, or for selecting a change. To start, click the appropriate **Keyboard** button.

Select some sounds by their features:	clear	keyboard	... and change them into these features:	clear	keyboard
---------------------------------------	-------	----------	--	-------	----------

¹ Notice that the precise appearance of the program may change according to your operating system.

This will bring up a little box in which you can type. You can enter the values in a single line in much the same way you would write them on paper. You enter the feature values separated by commas, and for each the value (+ or -) precedes the feature name. For example, you could type:

```
-consonantal, +high, +back
```

To save a little bit more time, you can abbreviate the feature names, as follows:

```
-conson, +high, +back
```

But you can't abbreviate to the point that ambiguity would be created. For example, you couldn't type

```
-cons
```

since in the feature system used by the program there is another feature that starts with "cons", namely [constricted glottis].

5.6 *Extracting feature lists to the clipboard*

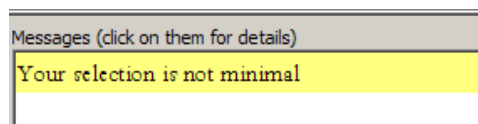
There is a second thing you can do with the keyboard entry boxes: no matter how you entered some features, they will be displayed when you view the keyboard box, and then you can highlight what you want with the mouse and click Control-c (similar keys are available in other operating systems) to copy the text to the clipboard. Then you can paste into a homework or paper.

6. Feedback and warnings

The panel on the top right of the main screen is devoted to messages pointing out issues with your feature selections. These messages are shown in a list format and a single click on them will bring up a window that gives more details about the message.

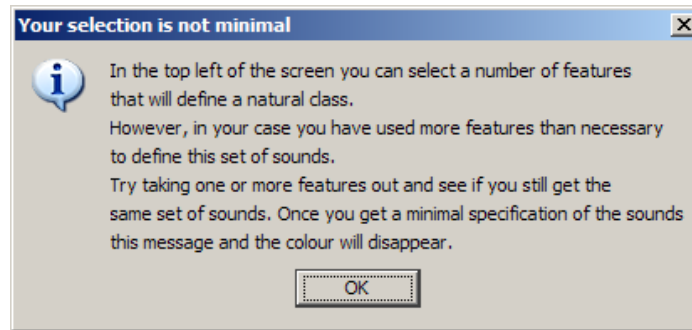
6.1 *Redundant features*

One kind of message tells you that your feature choices are redundant. Here is an example. If you are selecting the low vowels in the inventory, and enter [+low, -high] in the selection panel, a redundancy message will appear:



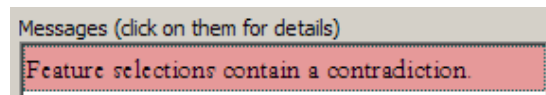
This is because any vowel that is [+low] is automatically [-high]. So you could have selected the same sounds by just choosing [+low].

If you click on the redundancy message, a box will pop up giving you more detail:

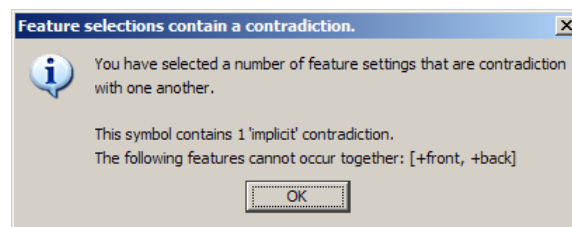


6.2 Contradictions

Another kind of message tells you about **contradictions**. A contradiction could happen, for instance, if you accidentally specified [+labial, –labial] as feature changes — this would be an overt contradiction. But the program is also on the lookout for *implicit* contradictions, which arise out of what features mean in the feature system. For example [+front, +back] is such an implicit contradiction, since obviously a sound cannot be both pronounced both in the front and the back of the mouth. Pheatures Spreadsheet responds like this:



Clicking on the message causes this to pop up:



6.3 Missing symbols

Any feature system of realistic size implies a huge number of possible feature matrices — the system used in Pheatures Spreadsheet allows about 23 trillion. Not all of these feature matrices can be expressed in IPA notation! This has practical implications, since often when you make a phonological change to a matrix, the result will be untranscribable — even by using the diacritics, the program is unable to find a way to depict the matrix derived by the change. In such cases, it displays a yellow or red question mark after the rightward arrow instead of a symbol. Naturally, this almost always means you've produced a wrong answer; normally we want our rules to produce actual output sounds in the language we're working on, and these will usually be transcribable in IPA.

6.3.1 What to do when you get a question mark?

Other than just thinking about the problem (which often works), there are three things you can do specifically with Pheatures Spreadsheet.

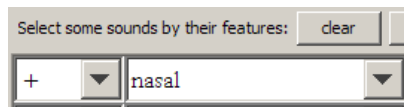
First, **double click** on the question mark. Sometimes this will cause the program to display a contradiction (see section 6.2), which you can then fix by changing more features.

Second, click on the cell in which sound occurs, *then* right click, then select **Show neighbors**. This will bring up a box that lists many sounds that are *close to* the ? sound, differing from it by just one or two (or a few) features. This list often includes the sound you're trying to derive. The features that are different are highlighted, so that you can see what additional feature changes you might need to make to yield the sound you wanted.

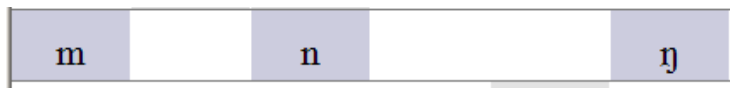
Third, you can use the **difference** utility. Undo all your selections, go to the phoneme inventory and Control-click² on two sounds (such that you want to derive one sound from the other). Then right click³ on one of the sounds, and select **Diff**. A window will pop up showing you all the features that differ in the two sounds — that is, the features you want to change.⁴

6.3.2 An example of how to deal with question marks

Suppose we're working with the German phoneme inventory, and we want to change the set [m n ŋ] (the nasals) into the corresponding voiceless stops [p t k] (there is no actual change like this in German, but does occur in other languages). It's easy to bring up the nasals by selecting the feature [+nasal].



yielding:



If, next, we (rather foolishly) choose to change only [–sonorant], we will get a batch of question marks:

² Depending your platform, the key might be called differently. Consult your familiar programs to see how multiple selections are handled there and it probably works the same in Pheatures Spreadsheet. All this happens because Pheatures Spreadsheet is programmed in Java, which copies the “look and feel” of whatever operating system it is running on.

³ This may once more depend on your operating system.

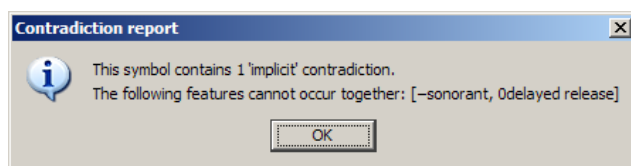
⁴ There is also a **Common** choice, which gives all the features that the two sounds share.

... and change them into these features:

—

m → ? n → ? ŋ → ?

We click on any of these question marks and a box pops up:



and the obvious remedy is to add [-delayed release] (the correct value for stops) to the change box:

... and change them into these features:

—

—

Now the question marks are yellow instead of red, which is progress.

m → ? n → ? ŋ → ?

We then follow the second method given in 6.3.1. Click on the m → ? box, then right click. Up pops a new box which contains a list of sounds that are *similar* to the ? sound.

Feature List

		syll...	stress	long	con...	son...	con...	del...	ap...	tap	trill	nasal	voice	spr...	con...	labial	round	labi...	cor...
(0)	?	—	—	—	+	—	—	—	—	—	—	+	+	—	—	+	—	—	—
(1)	b	—	—	—	+	—	—	—	—	—	—	—	+	—	—	+	—	—	—
(2)	m	—	—	—	+	+	—	0	—	—	—	+	+	—	—	+	—	—	—
(2)	p	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	+	—	—
(2)	b̥	—	—	—	+	—	—	+	—	—	—	—	+	—	—	+	—	—	—
(3)	ŋ	—	—	—	+	+	—	0	—	—	—	+	+	—	—	+	—	+	—
(3)	β	—	—	—	+	—	+	+	—	—	—	—	+	—	—	+	—	—	—
(3)	ɸ	—	—	—	+	—	—	+	—	—	—	—	+	—	—	+	—	+	—
(3)	p̥	—	—	—	+	—	—	+	—	—	—	—	—	—	—	+	—	—	—

We note, happily, that [p] is on this list, and that it differs from ? by the features [nasal] and [voice]. So we enter [-nasal] and [-voice] into the change box:

... and change them into these features:

-	▼	sonorant	▼
-	▼	delayed release	▼
-	▼	nasal	▼
-	▼	voice	▼
	▼		▼

and our problem is solved: the nasals are now turning into voiceless stops, as desired.

m → p n → t ŋ → k

However, we might have saved ourselves some trouble if we had planned in advance, and followed the third method given in 6.3.1. Specifically, we clear all of our selections, letting the full phoneme inventory appear, and control-click on [p] and [m]:

Spreadsheet Chart	
p	
b	
	p ^h
	f
	v
m	

and then right-click on either [p] or [m] and select **Diff**, we get this:

Feature List				
	son...	del...	nasal	voice
p	-	-	-	-
m	+		+	+

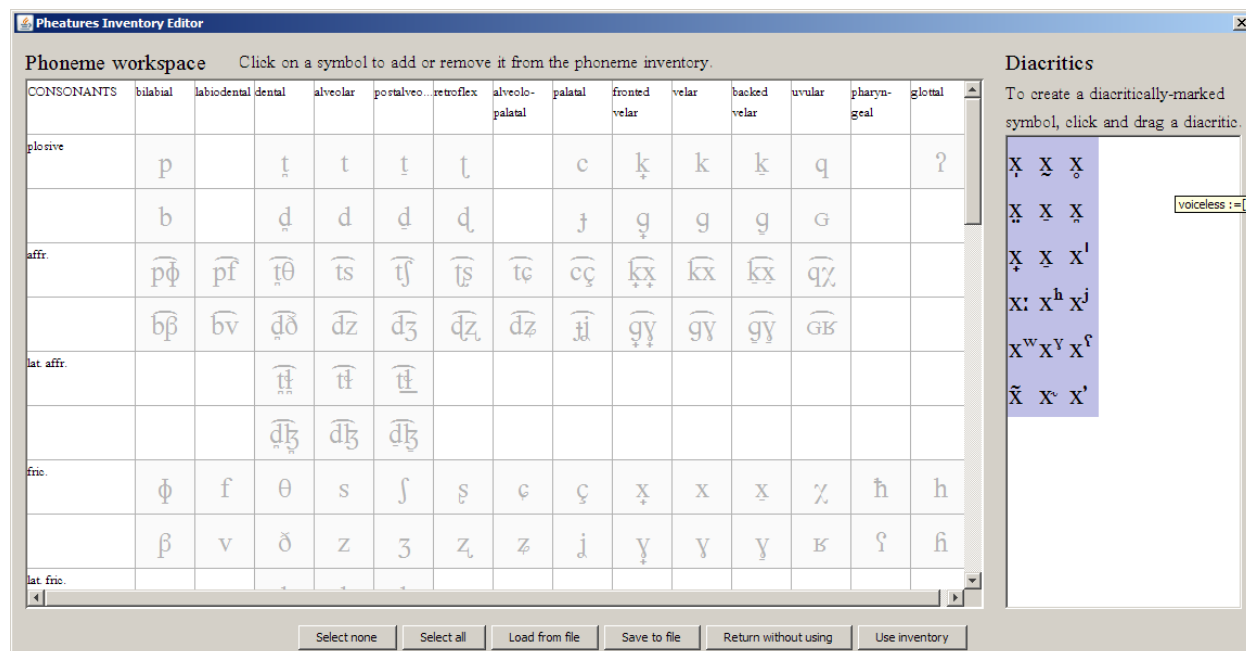
These are exactly the features we need to change to convert nasals into voiceless stops.

7. The phoneme inventory editor

Suppose you want to enter the phoneme inventory for a new language. From the **File** menu, select **New phoneme inventory**. This will bring up the inventory editor starting with an empty inventory.

Alternatively, if you would like to alter an existing phoneme inventory, then first open that inventory, then select the **Inventory** menu and choose **Edit phoneme inventory**.

The phoneme inventory editor contains a big chart with the plain symbols on the left, in IPA format, and the diacritics on the right.



To include a sound in your inventory, simply click on it once. You will notice that it takes a blue color, and this means you have successfully added it. Clicking on it again will remove it from the inventory, but leave a grayed out cell in the table in case you'll want to change your mind and add it later.

To add diacritics to the symbols, you can click on them and hold your mouse button while you drag them to the left on to the base symbol you want. This is called drag and drop, and again the precise implementation may depend on your operating system.

You will see that often a new row will appear in the table below the base symbol you selected and that the base symbol with its added diacritic appears there. This is done to keep the organization of the inventory editor intuitive. You can add another diacritic to a symbol that has already a diacritic by dragging it onto the diacritic-marked symbol in the main chart.

In some cases, you will not be able to add a diacritic to a symbol. In this case, it will light up red during the dragging and you will get an explanation message. Some diacritics have requirements on what sounds they can attach to. For example, the nasal diacritic [̃] can only attach to sounds that are [+sonorant, -nasal]. To gain information on this, you can right-click on the diacritic to bring up a screen with details.

Similarly, you can right click on symbols in the chart to see how they are composed of a base symbol and diacritics and what their features are.

Using the buttons in the bottom of the screen you can save your phoneme inventory to a file or load one from a file.⁵ You can close the screen by pressing either **Use inventory** or **Return without using**. If you want the phoneme inventory you have been working on to appear in the main screen, you can click **Use inventory**. Otherwise, click **Return** without using to abandon your changes.

Notice that even when you loaded an inventory from a file, you can safely use the inventory editor to add a sound or two to it, and then click **Use inventory**. The changes you made will not be saved to a file unless you click **Save** to file in the inventory editor, yet you will be able to use the updated inventory in the main screen.

8. Listing all the natural classes of a language

You can find *all* the natural classes that are defined by the feature system in the particular phoneme inventory you're using by selecting the **Inventory** menu, then **List Natural Classes**, then the **Start** button.⁶

Typically the number of natural classes is in the hundreds or low thousands. Bear in mind that any one natural class may have an enormous number of different descriptions using the feature system; Pheatures Spreadsheet gives you just one such description.

Once you've got all the natural classes, you can double-click on any one to automatically enter the features that define it in the selection panel.

9. Customizing the feature system

The feature system employed by Pheatures Spreadsheet is entirely customizable. You can change the set of base symbols, their feature values, the layout of the symbols in the chart, and the diacritics. This is not an easy task, and you should take it on only if you have serious reasons to do so. One reason changing the features is hard is that you have to work out all the contradictions (like *[+high,+low]) and logical implications (like [+round] → [+labial]) that are implied by your feature system.

To learn how to change the features by visiting the Pheatures Spreadsheet web site (<http://www.linguistics.ucla.edu/people/hayes/120a/Pheatures/>) and download the manual, *Pheatures Spreadsheet: How to Customize the Features*.

⁵ Note that these files are not compatible with files used in "FeaturePad", the predecessor program of Pheatures Spreadsheet.

⁶ Unfortunately, the **Export** button appears not to be working, at least in Windows; it's supposed to make a file with your natural classes but the phonetic font is lost. This needs to be fixed...

10. Credits and copyright

10.1 People

The idea for this program originates with Bruce Hayes, Professor of Linguistics at UCLA.⁷ The first implementation of this idea —“FeaturePad”— was implemented as Windows software by Kie Zuraw⁸, now also Professor of Linguistics at UCLA. Zuraw also designed much of the precise implementation of the feature system. Pheatures Spreadsheet adopts many of her algorithms.

The current Java-based implementation was designed and programmed by Floris van Vugt,⁹ at the time a graduate student of linguistics at UCLA. Some additional functionality such as Diff, Common and the natural class functions have been designed (in collaboration with Bruce Hayes) and written by Floris van Vugt.

The manual was written by Floris van Vugt and Bruce Hayes.

Pheatures Spreadsheet and its ancestor program FeaturePad were funded by two grants from UCLA’s Office of Instructional Development¹⁰ to Bruce Hayes.

10.2 Fonts and software resources employed by Pheatures Spreadsheet

The program uses the Doulos SIL Unicode-based IPA font, which is made available online by the Summer Institute of Linguistics.¹¹

The program is compiled using Sun’s Java Development Kit, version 1.6. It requires the Java Runtime Environment (JRE) 1.5 or higher to run. We recommend using Sun Java JRE, although other implementations have been tested as well. Mac OS X’s Java implementation has issues with the drag and drop interface, which may make the Inventory Editor unusable. Other than this, the program should work fine on all platforms.

10.3 Permissions and Copyright

As a student or teacher you are free and welcome to download and use Pheatures Spreadsheet. However, the program is copyrighted by the Regents of the University of California and may not be used for any commercial purpose.

⁷ <http://www.linguistics.ucla.edu/people/hayes/>

⁸ <http://www.linguistics.ucla.edu/people/zuraw/>

⁹ <http://www.florisvanvugt.com/>

¹⁰ <http://www.oid.ucla.edu/>

¹¹ <http://www.sil.org/>