



Autophon user guide

Icelandic

Model: IceFA 1.0 (bootstrapped)

1 Introducing Autophon and forced alignment

Autophon is a **free** online forced aligner. *Forced alignment* (FA) refers to the automatic process by which speech recordings are phonetically time-stamped with the help of Hidden Markov models or Deep Neural Networks. Autophon uses the latter by means of the *Montreal Forced Aligner*¹, which is built on the Kaldi toolkit². The app outputs a time-stamped phonetic annotation, readable in Praat (Boersma and Weenink 2017), that is based on an optimization of two user inputs: (1) the speech recording and (2) a corresponding orthographic transcription.

Forced alignment is important because it automates something that is resource-intensive when done manually. A typical phonetic annotation can take between 250 and 400 minutes per recorded minute. In a place like Scandinavia – where labor costs are high – this cost has presented a barrier for linguists.

For a forced alignment tool to work, an acoustic model must be trained on the specific language, and an accompanying pronunciation lexicon must be built that covers every word in the language (See section 5).

Numerous forced aligners are in circulation and available to download and use. However, they often are command-line based and rely on operating systems (OS) that may be outdated and/or incompatible with your OS. Therefore, *Autophon aims to offer an OS-agnostic and user-friendly option for phoneticians around the world.*

Bootstrapping For this language, Autophon has made use of a “bootstrap” model. This means that instead of training an entirely new model for *Icelandic*, we are using the model from *Norwegian* instead. It is relatively common practice for researchers of low-resource languages to bootstrap acoustic models from higher-resource languages before training a custom model³. The way we did this was as follows: (1) we first identified the properties of the phonemes in *Norwegian* and the phonemes in *Icelandic* according to the feature tables in Hayes (2009, pp. 95–97); (2) we calculated the Levenshtein distance between the phonemes as calculated, for example, in Gooskens and Heeringa (2004); (3) we matched the phonemes in *Norwegian* that had the shortest Levenshtein distance to phonemes in *Icelandic*; (4) for phonemes with more than one match, we consulted a word frequency list⁴, mapped the words to their phonemic annotation, calculated phoneme frequency from this mapping, and then selected the phoneme with the highest frequency. If your project should require a detailed account of the phoneme maps, Levenshtein distance charts, and/or phoneme-frequency data, simply contact tech support, and we will email over the datasets.

2 Using the app

Logging in You can create an account by following the relatively intuitive guidelines on our website. We require an account because we wish to keep track of usage in order to make a case for funders. Furthermore, an open system makes us vulnerable to bot attacks. After registering, a verification email will be sent to you with a link that you must click on to verify your account. If you do not receive the email, first check your spambox and then wait at least 15 minutes before contacting tech support.

Cost Autophon is free of charge.

Adding files First go to the *Aligner* tab and click *Add files*. A box will appear with the heading *Transcription Mode: change transcription mode*. Click on the heading to select one of four *Transcription Modes*. Once your transcription mode has been selected, use the file browser underneath to select your files.

Transcription modes Four different *transcription modes* are available, each named according to the field in which the format is most common: *Experimental Linguistics A*, *Experimental Linguistics B*, *Computational Linguistics*, and

¹McAuliffe, Socolof, Mihuc, Wagner, and Sonderegger (2017)

²Povey, Ghoshal, Boulianne, Burget, Glembek, Goel, Hannemann, Motlicek, Qian, Schwarz, et al. (2011)

³Coto-Solano, Nicholas, and Wray (2018), Coto-Solano and Solórzano (2017), DiCanio, Nam, Whalen, Timothy Bunnell, Amith, and García (2013), Strunk, Schiel, Seifart, et al. (2014), and Young and McGarrah (2023)

⁴https://en.wiktionary.org/wiki/Wiktionary:Frequency_lists



Variationist Linguistics. Each can be selected by clicking on one of the boxes illustrated in Figure 1. The boxes illustrate a typical file structure for each mode and provide a link to a video that offers detailed formatting instructions.

Experimental linguistics A: In this mode, you upload a master transcription spreadsheet along with corresponding audio files – one by one or within a zip file. The master sheet should have two columns: column 1 holds the audio file names in your folder; column 2 holds the corresponding transcriptions. This format is similar to that used by, e.g., CommonVoice⁵ and assumes that each audio file contains a short snippet of speech, which means that time stamps are *not* permitted. If you have a master transcription spreadsheet with time stamps, you are in the wrong transcription setting and need to select *Experimental Linguistics B*, described below. The master transcription sheet can be in a two-column Excel **xlsx** or tab-delimited file with either the extensions **txt** or **tsv**.

Experimental linguistics B: In this mode, you also upload a master transcription spreadsheet with corresponding audio files – one by one or within a zip file. Unlike in mode A, it should have four columns: column 1 holds the names of the audio files in your folder; column 2 – start times; column 3 – end times; column 4 – transcription. This mode is designed for longer audio files that warrant multiple lines of transcription. The master transcription sheet should either be a four-column Excel **xlsx** or a tab-delimited file with either the extensions **txt** or **tsv**. Time stamps must be in *seconds formatted as real numbers*. European comma decimals are accepted (e.g., **1,23**) as well as Anglo-American period decimals (e.g., **1.23**). What will not work, however, are time stamps with colons, minutes, or hours (e.g., **00:00:01.23**).

Computational linguistics: In this mode, you upload pairs of **lab** and audio files by the same name – one by one or within a zip file. These so-called **lab** files are simply text files that contain a single transcription phrase that matches the speech within the same-named audio file. Importantly, transcriptions should contain no time stamps. If you wish to have a complex set of subfolders within the zip file, as is common for comp-ling corpora like, e.g., NST⁶, Autophon will output the finished TextGrids using the same folder structure. An example of one such folder hierarchy is shown in Figure 2

Variationist linguistics:⁷ In this mode, you upload pairs of transcription and audio files by the same – one by one or within a zip file. In contrast to the previous mode, transcriptions are longer and include time stamps that delineate the speech at the phrase level. Transcription files may be in Praat **TextGrid** or in ELAN **eaf** and may have multiple speaker tiers. Alternatively, transcription files may be in Excel **xlsx** or a tab-delimited **txt** or **tsv** file.⁸ You have the option of uploading a three-column or four-column file, depending on your needs. If the recording has multiple speakers, upload a four-column transcription file whereby column 1 holds the speaker name, column 2 – start time, column 3 – end time, and column 4 – transcription. If the recording has just one speaker, a four-column file is of course fine, but you may also upload a three-column file. Column 1 should hold the start time, column 2 – end time, and column 3 – transcription. Time stamps must be in *seconds formatted as real numbers*. European comma decimals are accepted (e.g., **1,23**) as well as Anglo-American period decimals (e.g., **1.23**). What will not work, however, are time stamps with colons, minutes, or hours (e.g., **00:00:01.23**).

Transcription codecs We have built Autophon so that it accepts transcription files in **most** codecs, and this is a vital feature for its OS-agnostic goal. Accepted codecs include, but are not limited to, UTF-8 Unix, UTF-16 Windows CRLF, Windows ISO Latin 1, and Windows ISO Latin 9. If you encounter errors, please email a sample file to tech support so that we can update our code with that format⁹

Audio codecs We have built Autophon so that it accepts audio files in **most** codecs, and this is a vital feature for its OS-agnostic goal. Accepted codecs include AAC(M4A), AC-3, AIFF, AIFF/24bit, AIFF/32bit, ALAC, FLAC, M4R, MP3, OGG, OPUS, WAV/8bit, WAV/24bit, WAV/32bit, WAV/A-law, WAV/mu-law, and WMA. Autophon will automatically consolidate stereo files to mono, *which may compromise quality due to phase cancellation*¹⁰. Therefore, you may wish to explicitly select either the left or right channel of your stereo file before aligning. If you encounter errors, please email a sample file to tech support so that we can update our code with that format¹¹

⁵<https://commonvoice.mozilla.org>

⁶<https://www.nb.no/sprakbanken/en/resource-catalogue/oai-nb-no-sbr-16/>

⁷This also happens to be the field that originally kickstarted forced alignment back in the early 2000s.

⁸The tab-delimited format is similar to the input format that was used for the legacy Penn Forced Aligner and FAVE Align.

⁹In the meantime, a quick fix is to open and resave them in a current version of Praat or ELAN.

¹⁰For more on phase cancellation, check out <https://youtu.be/wY9QokRPJts>

¹¹In the meantime, a quick fix is to convert the file to WAV using software like FFmpeg or MediaHuman audio converter.



Experimental Ling A (click to see video guide)	Experimental Ling B (click to see video guide)	Computational Ling (click to see video guide)	Variationist Ling (click to see video guide)
<pre>yourzip.zip ├── yourtrans.xlsx/tsv/txt ├── file0001.wav ├── file0002.wav ├── file0003.wav ├── ... └── file9999.wav</pre> <p>Transcriptions in a master file absent of time stamps - as separate rows with separate audio* files for each transcription.</p>	<pre>yourzip.zip ├── yourtrans.xlsx/tsv/txt ├── file01.wav ├── file02.wav ├── file03.wav ├── ... └── file99.wav</pre> <p>Transcriptions in a master file with start and end time stamps with more than one row per audio* file.</p>	<pre>yourzip.zip ├── file0001.lab ├── file0001.wav ├── file0002.lab ├── file0002.wav ├── file0003.lab ├── file0003.wav ├── ... ├── file9999.lab └── file9999.wav</pre> <p>Transcriptions as separate same-name lab and audio* files, absent of time stamps.</p>	<pre>yourzip.zip ├── file01.TextGrid ├── file01.wav ├── file02.eaf ├── file02.wav ├── file03.tsv ├── file03.wav ├── file04.xlsx ├── file04.wav ├── ... ├── file99.txt └── file99.wav</pre> <p>Longer transcription files in TextGrid, eaf, tsv, txt, or xlsx format with same-name audio* files.</p>

Figure 1: The Transcription Mode selection menu for Autophon.

The diagram illustrates the output of Autophon. On the left, a folder structure for 'daDK_small' contains subfolders 'X0297' and 'X0298'. 'X0297' has subfolders '1' and '2', with '2' containing 17 audio (.wav) and lab files. 'X0298' has subfolders '1', '2', and '3', with '1' containing 10 audio (.wav) and lab files. On the right, the same folder structure is shown, but the audio and lab files have been replaced by TextGrid files with the same names and subfolder structure.

Figure 2: Autophon will output the finished TextGrids using an identical subfolder structure as the uploaded file.

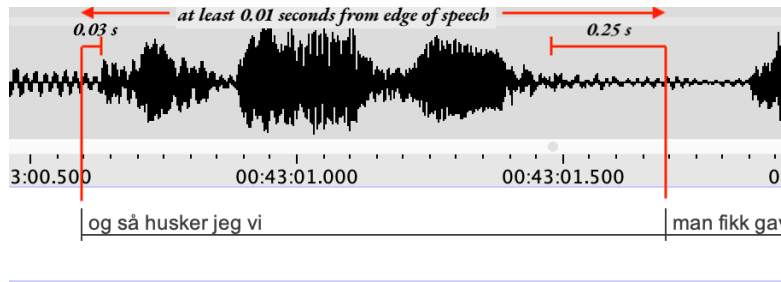


Figure 3: A sample transcription with at least 0.01 seconds of buffer on either end of the speech stream.

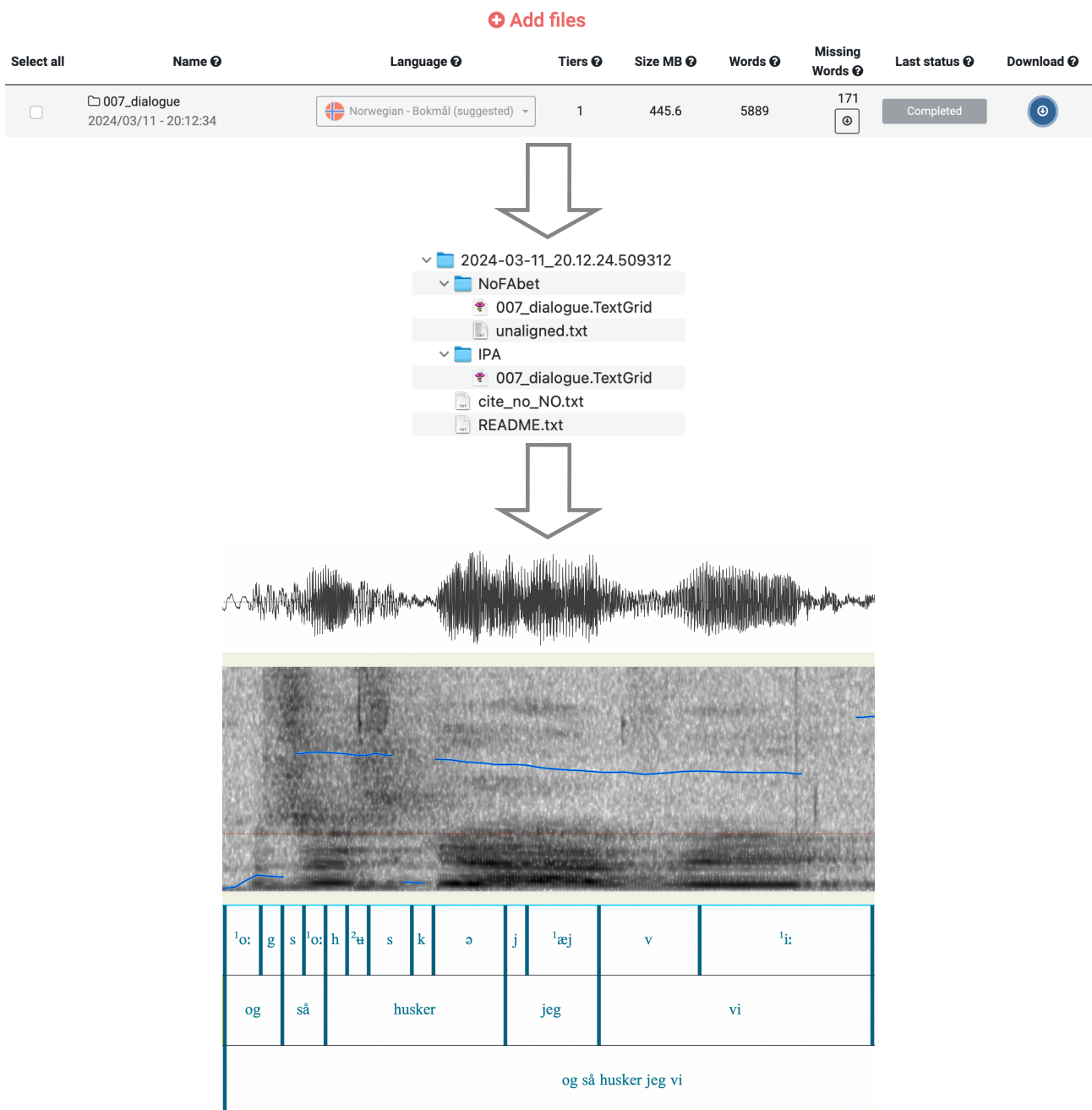


Figure 4: The alignment process, including task list, folder structure, and Praat TextGrid.



Transcription preparation Regardless of what transcription mode you use, transcriptions should contain between one and 20 words. Boundary demarcations should have at least 0.01 seconds of buffer before and after the speech stream. This is illustrated in Figure 3, which shows a five-word phrase with a start boundary 0.03 seconds from the speech and an end boundary 0.25 seconds from the speech. Varying the boundary demarcation in this way is expected, and Autophon handles it well¹²

Select a language Once you upload your files into the aligner, it will suggest a language and language model. You are welcome to change the selection using the dropdown menu.

Task list The task list shows all uploads and includes metrics like file name, upload date, language, tier count, file size, word count, and an inventory of missing words. You can either delete the task and start over, add words to your *custom pronunciations* box (described below), or proceed by clicking *Align*.

Missing words This feature can be understood if you have a basic understanding of how forced alignment works. Forced alignment maps a pre-defined phonemic pronunciation onto the speech stream by means of Deep Neural Networks. These pronunciations are defined by language-specific dictionaries that hold a finite list of words. The *missing words* feature provides a list of words not found in Autophon's dictionary and suggests a corresponding pronunciation. Autophon will simply default to using those suggestions for alignment, but you also can reject a suggestion and enter your own pronunciation. This process is described in the next section.

Your custom pronunciations As described above, forced alignment maps pre-defined phonemic pronunciations onto the speech stream by using language-specific dictionaries that hold a finite list of words. For missing words, Autophon suggests a pronunciation. You may decide that you either (a) do not agree with Autophon's missing words suggestions or that you (b) do not agree with the pronunciations within the language-specific dictionary. In this box you can enter your own pronunciations that will override both.

Pronunciations must be entered using the ASCII string specific to the language model at hand – in this case, Grammatek X-Sampa. Table 1 holds a key for Grammatek X-Sampa and its respective IPA¹³ equivalents. You may type pronunciations directly into the dictionary box or upload them from a **txt** file. You are limited to 1 million characters. Entries must be formatted as **word-space-phoneme-space-phoneme** or **word-tab-phoneme-space-phoneme**, which means that each phoneme must be separated by a space. Note also that the lookup cannot be two or more words because that will confuse Autophon and make it treat the second word as a phone.

You may enter more than one pronunciation for the same word by repeating the word on the next line and providing a different pronunciation. Autophon will respond by attempting to find the most suitable pronunciation for that specific speech event. See below for examples of correct versus incorrect entries.

§ *Correct vs. incorrect entries in the "Your Custom Pronunciations" box.*

Correct:

```
congratule    k N g R a t y l
congratule    k N R a t y l
con_gratule   k N g R a t y l
```

Incorrect:

```
congratule    k N gR a t y l (phones missing a space between them)
con gratule    k N g R a t y l (two look-ups on a single line)
```

Aligning files Click *Align* to the far right of the upload list to initiate alignment. This will usually just take a few minutes, depending on how many people are using the aligner at that moment.

Downloading the annotations When alignment is finished, your annotations can be downloaded as Praat TextGrids via the downward arrow to the right of the task list. Figure 4 shows an example of this process.

¹²If you have transcriptions of single words or phrases that are segmented at the exact start and finish times. Autophon will perform poorly and move those boundaries. This, however, is something we would be interesting in remedying by means of a fifth transcription mode, so kindly reach out to tech support if you have such a project.

¹³International Phonetic Alphabet



3 How to cite

Any dissemination that makes use of Autophon Icelandic should cite the below references. We understand that publishers often pressure researchers to slim down bibliographies; however, this should be done on the literature review and not on core analysis tools. Our view is plain: failure to cite constitutes plagiarism.

- Boersma, P., & Weenink, D. (2017). Praat: Doing phonetics by computer [softw.], ver.6.0.36. www.praat.org
- McAuliffe, M., Socolof, M., Mihuc, S., Wagner, M., & Sonderegger, M. (2017). Montreal Forced Aligner: Trainable text-speech alignment using Kaldi. *Proceedings of Interspeech*, 498-502.
- Nikulásdóttir, A. B., Ármannsson, B., Bergþórsdóttir, B., & Rögnvaldsson, E. (2023, October). Icelandic Pronunciation Dictionary for Language Technology [Release 23.10]. <https://github.com/grammatek/iceprondict>
- Young, N. J. (2024). IceFA 1.0 - Forced Alignment of Icelandic (bootstrap), ver. 1.0. www.autophon.se
- Young, N. J., & Anikwe, K. (2024). Autophon - Automatic phonetic annotation of Nordic languages (web app). www.autophon.se

4 Phoneme key

Autophon will output two versions of the same TextGrid for every file you align: (1) a TextGrid in Grammatek X-Sampa¹⁴ and (2) a TextGrid in the International Phonetic Alphabet (IPA). The phoneme inventory for Icelandic is mostly identical to the inventory used for Grammatek's Icelandic Pronunciation Dictionary for Language Technology¹⁵, albeit with some minor adjustments, namely the addition of primary stress % in front of the first vowel for every word. The key is located in Table 1. We encourage users to inform us of errors and provide suggestions for changes.

X-Sampa	IPA	example	X-Sampa	IPA	example	X-Sampa	IPA	example	X-Sampa	IPA	example
Full vowels			Diphthongs			Consonants					
a	a	aska	ai	ai	ætla	c	c	gera	r	r	fara
a:	a:	aka	ai:	ai:	æfa	c_h	c ^h	kæla	r_θ	r̥	hráði
i	i	ískra	au	au	ást	f	f	finna	s	s	sofa
i:	i:	nýta	au:	au:	láta	h	h	halda	t	t	dalur
u	u	kústur	ei	ei	einn	j	j	játa	t_h	t ^h	tala
u:	u:	súpa	ei:	ei:	leika	k	k	galdur	v	v	vera
9	æ	öskur	Oi	oi	bogi	k_h	k ^h	kaldur	x	x	rækta
9:	æ:	böl	ou	ou	ósk	l	l	sæla	C	ç	hjóla
0	ɔ	ostur	ou:	ou:	ljós	l_θ	l̥	velta	D	ð	viður
0:	ɔ:	nota	9i	œy	haust	m	m	muna	G	ɣ	saga
E	ɛ	nesti	9i:	œy:	laus	m_θ	m̥	glampa	N	ŋ	langur
E:	ɛ:	lesa	Yi	yi	hugi	n	n	næla	N_θ	ŋ̥	hönk
I	ɪ	hitta	Stress			n_θ	n̥	hnefi	J	j̥	angi
I:	ɪ:	síður	%x	ˈx	aska	p	p	bera	J_θ	j̥	banki
Y	ʏ	undra				p_h	p ^h	pera	T	θ	punnur
Y:	ʏ:	muna									

Table 1: Phoneme key: Grammatek X-Sampa, IPA, and lexical examples. The prosodic denotation means that % can be written before any (Grammatek X-Sampa) vowel or diphthong to denote primary stress. Unstressed vowels take no denotation.

¹⁴Nikulásdóttir, Ármannsson, Bergþórsdóttir, and Rögnvaldsson (2023, October)

¹⁵Nikulásdóttir, Ármannsson, Bergþórsdóttir, and Rögnvaldsson (2023, October)



5 Acoustic model and pronunciation dictionary

IceFA 1.0 (bootstrapped) for Icelandic uses the acoustic model for Norwegian Bokmål, *NoFA version 1.0*, which was trained on Norwegian Bokmål from the RUNDKAST¹⁶ and NB Tale¹⁷ corpora. The pronunciation dictionary is adapted from *Grammatek's Icelandic Pronunciation Dictionary for Language Technology*¹⁸. One adjustment we made was adding a stress denotation % to the first vowel in every word in the dictionary¹⁹. Note that this was done with a universal script, so exceptions to the left-strong rule will be incorrectly denoted here in version 1.0. Note also that secondary stress is also missing. We are looking for co-authors to help improve our model and dictionary for the next version, so kindly contact us if you are interested²⁰.

6 Performance metrics

We currently have no performance metrics for *IceFA 1.0 (bootstrapped)*. If you are willing to provide us with a set of manually-corrected IcelandicTextGrids, we would be eager to validate our model with them (and update this document accordingly). As indicated above, we are seeking co-authors for future editions.

7 Data security and G.D.P.R.

The files you upload to Autophon are encrypted and sent to a server in Frankfurt, Germany, that is run by *Digital Ocean*. Transcriptions and audio files are deleted immediately after alignment, which significantly reduces the chance of a data breach and keeps our costs low²¹. On the other hand, finished TextGrids are stored in your account for as long as you like. Once, however, you delete them, they will be removed from our server permanently.

If you upload any files and fail to click on *Align*, Autophon will delete them at 3AM Greenwich Mean Time²².

We recognize our obligations to the European Union General Data Protection Regulation (GDPR), which is why we only collect four types of information from you: name, title, affiliation, and email address. Once you align a file, we permanently delete the audio. Once you delete the file from your task list, we also permanently remove the transcription and documentation of its original name. You may delete your account at any time, at which point we permanently delete your name, title, affiliation, and email address from our server. What we do *permanently* keep, however, is your alphanumeric account ID and the alignment activity linked to that ID – absent of original file names. We keep these records to show funders that Autophon is worth funding.

8 Features and limitations

What Autophon is: Autophon is a frontend web application for the Nordic languages that uses the Montreal Forced Aligner (MFA)²³ as a core component of its backend. The language-specific models and pronunciation dictionaries were constructed by Dr. Nate Young. The most significant pieces of the app's backend were constructed by Kaosi Anikwe who joined the project in early 2023. The language-specific models are trained on various corpora, and the pronunciation dictionaries are usually adaptations of existing dictionaries available online.

The main advantages of using Autophon are:

1. Autophon is a web app, which means it is OS-agnostic.
2. As a web app, it requires no programming knowledge, which expands access to researchers and students.
3. Autophon accepts nearly all types of transcription and sound formats.
4. Autophon has a limitless repertoire of pronunciations by making use of grapheme-to-phoneme algorithms.
5. Autophon has models for Nordic languages, which have typically been neglected by forced alignment tech.

¹⁶Amdal, Strand, Almberg, and Svendsen (2008)

¹⁷<https://www.nb.no/sprakbanken/en/resource-catalogue/oai-nb-no-sbr-31/>

¹⁸Nikulásdóttir, Ármannsson, Bergþórsdóttir, and Rögnvaldsson (2023, October)

¹⁹Árnason (2011, p. 271)

²⁰Email n8.young@gmail.com

²¹We pay Digital Ocean approximately 90 USD per month for 60 GB of space, which means we have thin margins and cannot store much data. This also happens to keep Autophon's carbon footprint relatively low.

²²Note that this means that if you are working late at night at, for example, 2.55 AM GMT, your uploaded files may disappear before you manage to align them. Bear this in mind.

²³McAuliffe, Socolof, Mihuc, Wagner, and Sonderegger (2017)



What Autophon is not: Important limitations are:

1. This is no magic bullet. Even with an accurate orthographic transcription, results may not satisfy.
2. Autophon varies in accuracy, and this accuracy depends on the language, speaker, and style.
3. Accuracy metrics are complex projects unto themselves, so they are unavailable for most languages.
4. Autophon will be slower to implement core MFA updates because it consists of layers and layers of code packed around MFA. For example, MFA 2.0 and 3.0 are not part of its backend yet.

9 Budget and funding

Autophon has cost ca. SEK 768 000 (ca. EUR 69 000) to develop and maintain since 2021. It was initially financed with private means by Dr. Nate Young but has since grown in scope with a grant from the Swedish Academy, a grant from the Department of Linguistics and Scandinavian Studies at The University of Oslo, and it has received funding from the European Union's *Horizon 2020 research and innovation programme* under the *Marie Skłodowska-Curie* grant agreement No 892963. Furthermore, The National Library of Norway funded development of the Norwegian Bokmål model²⁴.

We are actively looking for funders and collaborators who will support Autophon. We are also willing to share authorship with someone who can prepare grant applications and successfully procure funding. Contact us on the support page if you are interested.

Acknowledgements

Numerous individuals helped make Autophon possible. Michael McGarrh has offered important industry guidance, and Kaosi Anikwe has been an invaluable backend and frontend developer. Ismail Raji Damilola helped develop a bootstrapping function to adapt monophone inventories. The following programmers also worked on the app in its infancy: Nabil Al Nazi, Zamanat Abbas Naqvi, and Santiago Recoba.

References

- Amdal, I., Strand, O. M., Almberg, J., & Svendsen, T. (2008). RUNDKAST: An Annotated Norwegian Broadcast News Speech Corpus. *Proceedings of the Sixth International Conference on Language Resources and Evaluation (LREC'08)*. http://www.lrec-conf.org/proceedings/lrec2008/pdf/486_paper.pdf
- Árnason, K. (2011). *The Phonology of Icelandic and Faroese*. Oxford University Press.
- Boersma, P., & Weenink, D. (2017). Praat: Doing phonetics by computer [softw.], ver.6.0.36. www.praat.org
- Coto-Solano, R., Nicholas, S. A., & Wray, S. (2018). Development of Natural Language Processing Tools for Cook Islands Māori. *Proceedings of the Australasian Language Technology Association Workshop 2018*, 26-33.
- Coto-Solano, R., & Solórzano, S. F. (2017). Comparison of Two Forced Alignment Systems for Aligning Bribri Speech. *CLEI Electronic Journal*, 20(1), 2-1.
- DiCanio, C., Nam, H., Whalen, D. H., Timothy Bunnell, H., Amith, J. D., & García, R. C. (2013). Using automatic alignment to analyze endangered language data: Testing the viability of untrained alignment. *The Journal of the Acoustical Society of America*, 134(3), 2235-2246.
- Gooskens, C., & Heeringa, W. (2004). Perceptive evaluation of Levenshtein dialect distance measurements using Norwegian dialect data. *Language Variation and Change*, 16, 189-207.
- Hayes, B. (2009). *Introductory Phonology*. Wiley-Blackwell.
- McAuliffe, M., Socolof, M., Mihuc, S., Wagner, M., & Sonderegger, M. (2017). Montreal Forced Aligner: Trainable text-speech alignment using Kaldi. *Proceedings of Interspeech*, 498-502.
- Nikulásdóttir, A. B., Ármannsson, B., Bergþórsdóttir, B., & Rögnvaldsson, E. (2023, October). Icelandic Pronunciation Dictionary for Language Technology [Release 23.10]. <https://github.com/grammatek/iceprondict>
- Povey, D., Ghoshal, A., Boulianne, G., Burget, L., Glembek, O., Goel, N., Hannemann, M., Motlicek, P., Qian, Y., Schwarz, P., et al. (2011). *The Kaldi speech recognition toolkit* (tech. rep.). IEEE Signal Processing Society. Piscataway.
- Strunk, J., Schiel, F., Seifart, F., et al. (2014). Untrained Forced Alignment of Transcriptions and Audio for Language Documentation Corpora using WebMaUs. In N. Calzolari, K. Choukri, T. Declerck, H. Loftsson, B. Maegaard, J. Mariani, A. Moreno, J. Odijk, & S. Piperidis (Eds.), *Proceedings of the Ninth International Conference on Language Resources and Evaluation: May 26-31, 2014* (pp. 3940-3947). European Language Resources Association (ELRA).
- Young, N. J. (2024). IceFA 1.0 - Forced Alignment of Icelandic (bootstrap), ver. 1.0. www.autophon.se
- Young, N. J., & Anikwe, K. (2024). Autophon - Automatic phonetic annotation of Nordic languages (web app). www.autophon.se
- Young, N. J., & McGarrh, M. (2023). Forced alignment for Nordic languages: Rapidly constructing a high-quality prototype. *Nordic Journal of Linguistics*, 46(1), 105-131. [\nolinkurl {https://doi.org/10.1017/S033258652100024X}](https://doi.org/10.1017/S033258652100024X)

²⁴<https://www.nb.no/sprakbanken/ressurskatalog/oai-nb-no-sbr-59/>