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- **Introduction**

In an oversaturated market that offers really complex instruments and audio effect processors, I have considered interesting trying to build an instrument that is simple to use but can inspire musicians and producers from around the world. For that reason, I have decided to build a grain delay audio effect in Reaktor that freezes small grains of audio and allow to manipulate the sound in unexpected ways. This can lead to create new timbres that couldn't be achieved with more standard ways of synthesis as subtractive synthesis or FM synthesis. The motivation behind this idea is the thought that having some limitations can be way more stimulating and sparking than having endless possibilities during the creative process.

Although the textures and timbres can always be resampled and used in a sampler to play melodies chords and other musical figures (which is one of the most powerful uses of this effect), the main goal of this module is processing the audio to create lush soundscapes, glitterings and glitches sounds, rather than being triggered by midi notes or inputs as an standard instrument.

Some people that have tried to work with granular synths or grain delay audio effect often found that granular processing can be chaotic, difficult to dominate and mainly useful for creating sound effects. That is why I have the intention of building an audio effect based in granulation that is simple to use and, even more important, that looks simple. Because I have spent a lot of time working with granular type effects and synths, I know that it's possible to achieve very musical and rhythmical results that are beyond the reach of other types of effect, but sometimes really complex and intimidating interfaces can be difficult to understand and spend the necessary time to control them.

In addition, I consider that music technology and sound design are increasingly becoming an essential part in the music composition process. This not only applies to electronic music, but also to pop, hip hop and other commercial genres, as well as to scoring for film, tv and advertising and to soundscapes and 3D audio installations. For that reason, I take into consideration that it is necessary to look for and create new ways of sound design and production, to help the music industry keeping developing and progressing to new genres and artistic movements.

In other words, one of my intentions with building this grain delay audio effect is making something that can be useful during the sound design process to create sounds that couldn't be made in any other way.

- **Principles behind how my instrument works**

To understand the principles behind how my instrument works is necessary to distinguish between the different concepts that define the way it is build and the different audio effects that act as a foundation of this kind of processing.

First, it's necessary to understand the concept behind how delays work, one of the most used and useful audio effects in music production and, also, one of the core foundations of my module. Basically, a delay is an audio processing effect that records an input signal to an audio storage medium, and then plays it back after a determined period of time that can be modified throughout the different controls that this effect has.

The way they work is based in sending the input signal to the output one at a later time (this is defined by the delay time), which can be mixed with the original signal in different amounts. Moreover, delays usually have a feedback control that determines the number of repetitions that the delayed signal is reproduced. In addition, it is important to outline that any delay under 10-20ms won't be perceived as a separate signal from the original, only when the delay time is above 20ms our ears will perceive it as a different sound.

Some of the common uses of delays are achieving space and depth in a mix, making rhythmic effects and using it to achieve other effects that are originated from delays such as reverb, chorus or flanger. There are various types of delays, as mono and stereo delays, multi-tap delays, slap back delays and grain delays (the group where our instruments belongs).

Secondly, and before explaining the basis of grain delays, I will briefly describe the principles of granular synthesis.

The term granulation refers to the process in which an audio sample is broken down into small segments of audio called 'grains'. These grains can then be layered on top of each other and can be played within different speeds, pitches and formants variables, achieving textures and musical timbres that couldn't be reproduced using other types of sound creation techniques.

Thirdly, resampling is a process that is going to be involved for using the resulting effected samples of my grain audio effect and it can be described as the process of re recording audio into your digital audio workstation to then use it as a source for sampling or other sound design techniques.

Once I made the decision of building a module based on an audio effect that works with granular synthesis, I explored the different options that Reaktor offers to create that kind of ensemble. The two main ones were the Grain Delay module and the Grain Cloud Delay module.

[see Fig.1]

After going through the parameters and options that both offer, I came to the conclusion that the Grain Cloud Delay is more flexible for doing different types of granular sampling processing, due to that it offers more control inputs and it can have much larger grains that can overlap between them, which can be established in the module attributes.

On the other hand, the grain delay is useful as a pitch shifter delay, but not as good when trying to achieve granular type textures and timbres.

- **Process of building the audio effect**

Firstly, before opening any module, I went to the function window on Reaktor and brought the number of voices to 1, in order to avoid possible CPU problems when the instrument is finished, due to that I'm building an audio effect and I won't need those extra voices.

[see Fig. 2]

After that, I created a Grain Cloud Delay module on the Reaktor panel. The Grain Cloud Delay module can be found in 'Build-In Module' - 'Delay' - 'Grain Cloud Delay', or simply typing it on the command.

[see Fig. 3]

Once I had the module, I created controls for the parameters that were going to be on the instrument panel as knobs to tweak and help the user designing the sound. These parameters are: Freeze, Pitch, Freeze, Pitch, Delay, Grain Length, Attack, Decay and Distance. [see Fig. 4]

Next, I made some changes on the parameters ranges to enable to get interesting and musical timbres that can be used in sound design and commercial productions. The controls that I spent the more time with trying different numbers as maximum and minimum values and step size ranges were the Grain Length and the Distance of the playback region. This is because these two controls are the ones that influence the most the rhythmic and sound quality result of the grains that are selected to produce the sound.

Then, after doing some research I found that using a math Multiply module for setting exponential curves could help to make more musical and melodic sounds. So I opened a Multiply module and patch it with the grain length and the distance to the distance again (as we can see in the image below), making the distance of the grain always multiple of the grain length, allowing for more musical sensible distances between the grains.

[see Fig. 5]

After that, the audio effect is mono, so by duplicating the main Grain Cloud delay I created a stereo audio effect. Consequently, I used one of the Grain Cloud Delays routed to the left channel (both input and output) and the other one to the right channel (R input and R output).

[see Fig. 6]

Additionally, I thought that adding a filter in the module could be useful for getting better results during the sound design process, as well as offering more possibilities to the future users. After trying some of the filter modules that Reaktor offers, I decided to use the module Pro-52 Filter (this particular filter is a throwback module that is originally from the Pro-53 synth that Native Instruments released several years ago and is recognised as being a solid lowpass filter).

For patching it, I had to insert an Adder module for converting two signals into just one, due to that Filter module has only 1 input. Then, I patch it and I created controls for the linear Filter Cutoff, the logarithmic Filer Cutoff and the Filter Resonance and patch it to the outputs signals of the instrument.

[see Fig. 7]

[see Fig. 8]

- **Details of issues I have encountered while creating the instrument**

The main issue that I encountered in the early stages of the process, was trying to find the right values (maximum, minimum and step size values) for the distance and the grain length controls. This was really important, because being able to set the appropriate ones helped to get interesting and musical timbres that can be used in sound design and commercial productions.

For the Distance, after trying different minimum and maximum values, using 2 as maximum and 0.1 as minimum worked enough. As to the step size, I decided to set a really small measure to help finding interesting timbres and textures, which was the main goal of this audio effect.

[see Fig. 9]

Regarding the Grain Length values, I have tested different numbers until finding those who make easier to find musical timbres and rhythmic patterns that could be used in a musical composition. The values are: 200 for maximum, 10 for minimum and 0 for step size, as it enables to be extremely precise while moving the knob.

[see Fig. 10]

The second issue that I found was regarding the adding the filter to the patch. So, when adding the filter to the delay, I found that all the filter modules in Reaktor worked with just 1 Input and 1 Output routing, so that I couldn't patch the filter directly into my system. For making it possible, I used an Add Math module from Reaktor as a signal path between the output of the Grain Delay (L/R), converting the signal into just 1 output that then is routed to the Filter input, making the connection worked.

Finally, I found an issue with the heavy CPU usage, so I increased the buffer size to 1500 ms and the Quality to High Quality Interpolation.

- **Reflection upon the results of the instrument**

Now that the instrument is finished, I consider that with more hours of work I could have built a more precise and advanced audio effect. I think that the main functionalities of the instruments are already working and, therefore, the core of my idea is already made. Nevertheless, I think that the instrument might have been superior if I had been able to add the option of mapping modulations such as LFO's and envelopes to the Distance, Grain Length and Delay knobs, giving the users more options to find interesting sound movements and modulations.

Besides, I studied the addition of a *dry/wet* control but, after trying it, I decided that it was not useful enough because the main application of this audio effect is to generate a new sound from an original sample source, but not to blend them together.

For that reason, I give consideration to continue working on this synth to implement those functionalities and think about other ways to make it more versatile and interesting to the synth Reaktor community and any other future users.

- **Discussion of improvements that could be made to the instrument**

After evaluating the results of my instrument, I have come to the conclusion that the following improvements and changes could be applied for achieving a better and more efficient sound design tool.

Firstly, it is unavoidable thinking about what could have been the end result if I have chosen to use any of the other options within Reaktor at the start of the process, such as the Grain Delay or the Grain Cloud Sampler modules. Specially the second one and its capability to use audio directly in the ensemble opens up a discussion about what is the best option for this kind of granular based instruments. If we take the options that Ableton Live propose to their user for this kind of synthesis and audio processing as an example (Grain Delay, GrainFreeze, Grain Crusher, Grain Reverser and Grain Cooler), only the first one allows to import audio directly in the module, working more as a sampler rather than just as an effect. But it seems clear that there is a clear distinction between two different product lines: granular samplers and granular audio effects. Therefore, future improvements and implementations for my instrument should be made aiming for developing an interesting product for the second product line mentioned before.

One of the most interesting additions that could be made to the actual instrument would be the implementation of modulations such as LFO, ADSR envelopes or sequencers. Using them to modulate the Grain Length, the Delay Position or the Pitch would allow to offer more options to the user to create more complex timbres and sound movements.

A further feature would be adding some sort of random modulation similar to the Spray function of Ableton's Grain Delay. Something like that would be useful for creating unexpected effects, although the concept of my synth was to create something easy to use to achieve musical tones. Therefore, adding a random modulation could make the synth unpredictable and difficult to control.

Another possible feature would be adding a dry and wet control to mix the grain delayed signal with the original one. However, this is something that I consider during the building process but decided to dismiss due to that I consider that it wouldn't be too valuable or useful.

Furthermore, adding audio effects such as reverb or chorus to the module would be really interesting and an additional feature that could help the instrument to gain more value and capabilities of processing the sound for achieving more depth and character. However, it is true that these effects can also be added outside Reaktor and, therefore, maybe it would be better to focus on developing more unique attributes from this kind of grain audio effect delay.

Another implementation that could be useful is designing a better interface to help the users to work faster and easier. For that, one option would be rearranging the disposal of the different knobs, the freeze button and the playback region windows, in a simpler and more minimal way, trying to avoid any possible confusion or misunderstanding. On the other hand, counting on a graphic or product designer's collaboration could help to build a better appearance.

Finally, a reversed button to allow the users to reverse the sound direction (from the end to the start of the sound) with just a click would be a really interesting feature that could add more value and potential to my instrument.

- **Market research: trends, cost, competitors and users**

Trends

Regarding the current trends of the market, granular synthesis is increasingly becoming to play an important role in sound design and it looks like this growth is going to continue for the next few years, as we can see specially in the electronic music scene, where more and more artists are starting to use and add this granulation type sound to their productions.

Costs

With respect to the costs of developing and improving the instruments, they will be more related to time rather than money, due to that this is a simple software ensemble compared to more complex and advanced products. Nevertheless, it can't be discarded to spend some money on having a better design and more advanced ensemble in the future. In that case, the costs will mainly be spent on investigation, market research, user tests and hiring a designer to create a brand identity for the instrument.

Competitors

Concerning the competitors that my instrument will have on the market, I have separated them into three different groups, in descending order of similarities regarding price, capabilities and interface.

Firstly, the main competitors are similar Reaktor grain audio effects modules as 'Grain' (by David Elson), 'Grain Perception' (by Z Gabr), 'Grain Freeze' (by colugo), 'Live Grain Cloud' (by chris list) and 'Purform Granular Delay' (by Peter Dines).

One of the best advantages that my instrument has in comparison with this group of competitors is that it has been built with the latest version of Reaktor, so it works with any other version of the software. On the contrary, some of the similar grain freeze delays mentioned above were made with old versions of Reaktor and, therefore, don't work with the newest version of the program.

The second group of competitors are grain delay effects outside the Reaktor user library, such as Ableton's Grain Delay and Grain Scanner, the Granular Delay in Native Instrument's Guitar Rig and HiFi Grain Delay (by Tebgeronimo) on Max for Live. Although some of these competitors offer more possibilities for modulation and a more advanced deep processing, the fact that they work in a different software and that they are not free, make them less important to deal with when thinking about how to mark my instrument.

Thirdly, the last category of competitors are grain type effects and advanced granular synthesisers that offer a lot of possibilities to modulate different parameters of the sample used for the granulation, as well as post processing filters and a much more precise way of selecting the grains used for this technique. Some of them are 'The Mangle' (from SoundGuru), 'Crystalizer' (from SoundToys) and 'Granulizer' from Inertia Sound Systems.

After analysing the different competitors that are on the market, I have decided to focus my marketing strategy on ways of overcoming the competitors of the first group, the ones that work on Reaktor and are also offered on the user library web.

• Users

Regarding the potential users that might be interested and find useful to use this Reaktor module, the first ones would be producers interested in granular sounds and textures, in particular those who might be looking for ways of creating granular timbres using an audio effect instead of a sample based granular synth. Equally important, sound designers and scoring composers are another target for this module, due to their need to constantly look for new sounds and avant-garde creative tools for their studio.

- **Marketing strategy**

Afterwards, I must consider how I would reach my potential customers. Firstly, one of the best ways to offer this kind of Reaktor modules is through the Reaktor user library web (<https://www.native-instruments.com/es/reaktor-community/reaktor-user-library/>), where users are able to look for new instruments using a search tab to find what they are interested in. For marketing my instrument in this library, the most useful thing would be having a well design instruments that is appealing and looks user friendly, as it was one of my first goals when I started considering building this module. Furthermore, using a creative or even a funny name to market my instrument can help me to grab the attention of a lot of followers. After that, it is really important including some kind of audio demo linked next to the description, considering that showing the sounds that my effect is able to produce can be efficient and useful to connect with customers than just words. Having said that, I will also include a briefly description of the capabilities and functions that my grain delay can offer to my audience.

Another interesting way of promoting my ensemble would be using the forum and network reddit, specifically the subreddit */reaktor* (<https://www.reddit.com/r/reaktor/>). There, I would post a similar publication than on the Reaktor user library, with a download link and the audio demos as well.

Finally, recording a short video demonstration of how to use the instrument would be an essential tool for differentiating from the competitors (there are a lot of similar instruments that don't offer any video demo or tutorial) as well as showing the main features and functions of it. In the video, I will explain first the main features and principles behind how the audio effect works. Then, I will use different audio sample sources as vocals, pianos or guitars to show the different type, quality and timbre that it is possible to generate with it.

- **User feedback and beta testing of the instrument**

Finally, although I haven't been able to test the instrument with other users yet, all the trials and errors that I have done with it had showed me and help me to understand which controls need adjustments and which don't, as well as helped me identify difficulties to use the instrument and give me ideas for future implementations.

Nevertheless, I consider that doing tests with other users and asking for feedback could help the me to better understand the problems that the audio effect might have.

APPENDIX: FIGURES and PROCESS OF BUILDING THE SYNTH

Fig.1: Two main grain delay options
in Native Instruments Reaktor 6.

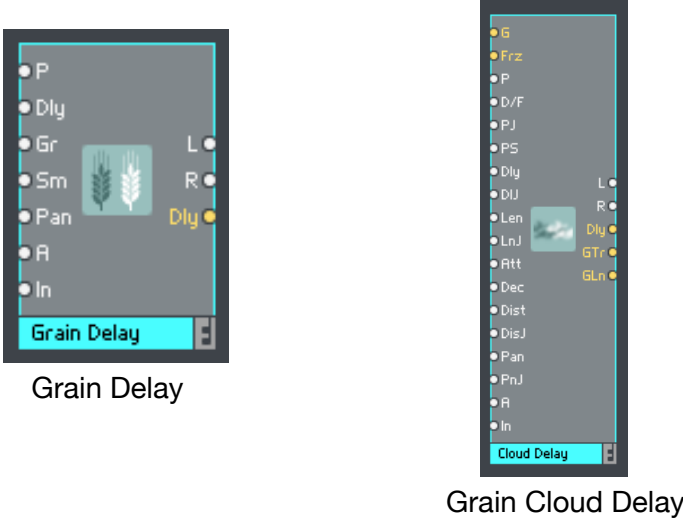


Fig.2: Choosing number of voices in Native Instruments Reaktor 6.

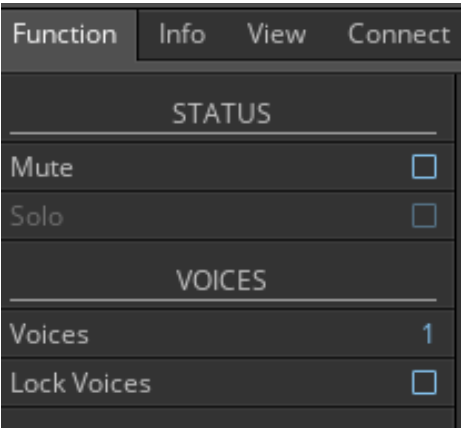


Fig.3: Creating a Grain Cloud Delay module on the Reaktor
panel.

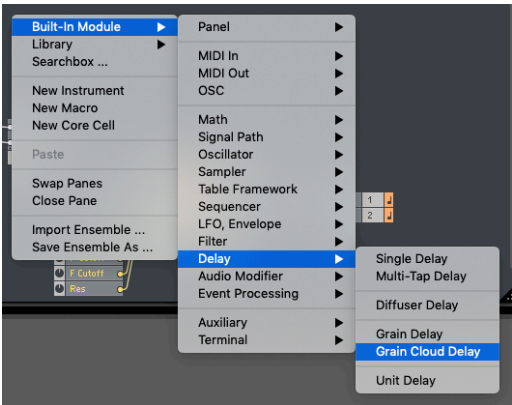


Fig.4: Creating controls for the main parameters: Freeze, Pitch, Freeze, Pitch, Delay, Grain Length, Attack, Decay and Distance.

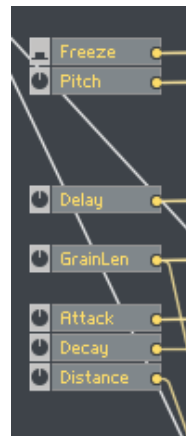


Fig.5: Using a math Multiply module for setting exponential curves.

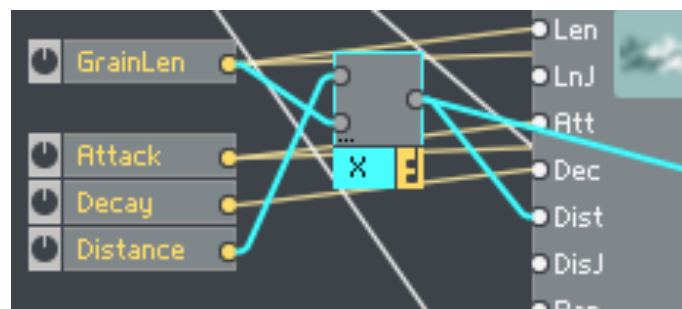


Fig.6: Duplicating the main Grain Cloud delay to convert from mono to an stereo audio effect.

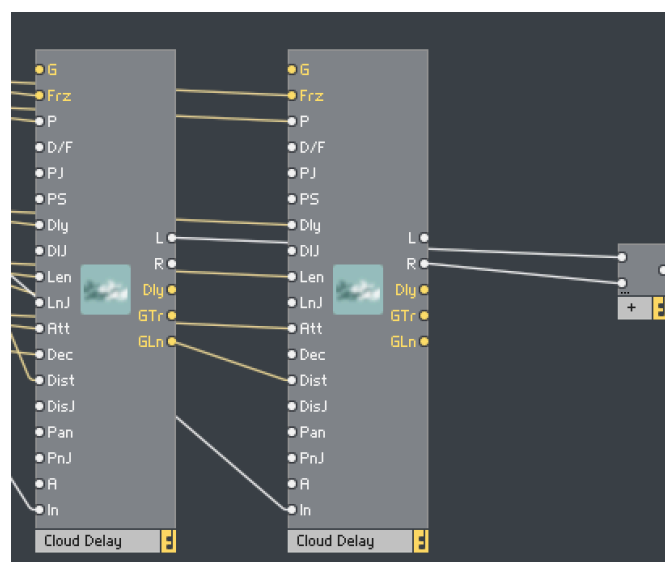


Fig.7: Final Patch module panel.

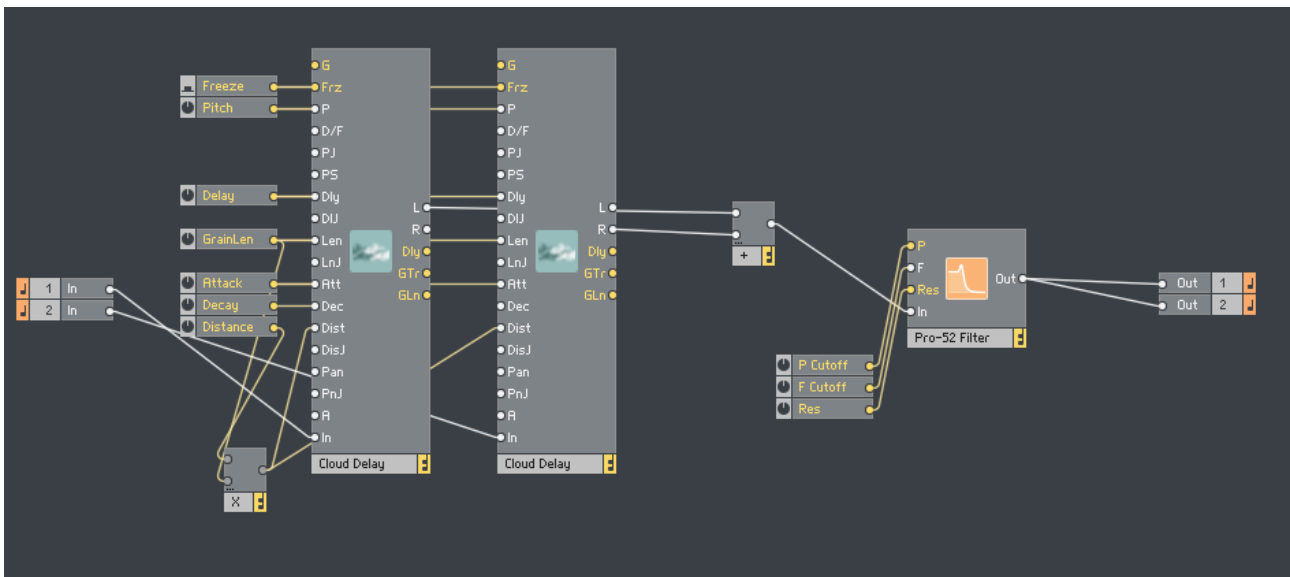


Fig.8: Final Patch ensemble instrument.



Fig.9: Setting the distance values: maximum, minimum and step size.

REAKTOR	
Fader	Distance
Function	Info View Connect
RANGE	
Max	2
Min	0.1
Default	1.3
Step Size	0.05
Mouse Resolution	100
Fine-tuning Factor	10

Fig.10: Setting the grain length values: maximum, minimum and step size.

REAKTOR	
Fader	GrainLen
Function	Info View Connect
RANGE	
Max	200
Min	10
Default	105
Step Size	0
Mouse Resolution	127
Fine-tuning Factor	10

Bibliography of Secondary Research:

Paul, L. (2011) *Granulation of Sound in Video Games*

Truax, B. (1990) *Composing with Real-time Granular Sound*. Perspectives of New Music. USA: Hamilton Printing Company. Pages 120-134.

Roads, C. (2002) *Composing Electronic Music: A New Aesthetic*. Book with audio excerpts. Oxford University Press.

Welsh, F. (2006) *Welsh's Synthesizer Cookbook*.

Video tutorials with Reaktor:

[1] Introduction to the Grain Cloud Delay module: <https://www.youtube.com/watch?v=JzpulPtNzGI>

[2] Setting up the Grain Cloud Module: <https://www.youtube.com/watch?v=KS5YN4PO9BQ>

[4] Modulating the Grain Cloud Delay: <https://www.youtube.com/watch?v=alhKWgQBj9o>

[5] Creating a filter with modulation: https://www.youtube.com/watch?v=WASRhDnn_OE

Other referenced links:

[a] https://www.native-instruments.com/fileadmin/ni_media/downloads/manuals/REAKTOR_Factory_Library_Manual_English_2015_11.pdf

[b] <https://www.soundonsound.com/techniques/granular-synthesis>

[c] <https://reaktortips.com/>

[d] <https://www.soundonsound.com/techniques/creating-using-custom-delay-effects>

[e] <https://producelikeapro.com/blog/understanding-granular-synthesis/>

[f] <https://www.marketwatch.com/press-release/music-synthesizers-market-2020-global-size-growth-insight-share-trends-industry-key-players-regional-forecast-to-2023-2020-03-04>

[g] <https://www.researchandmarkets.com/reports/4801835/global-music-synthesizers-market-2019-2023>