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Parameter Estimation of FM synthesis

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Abstract
FM synthesis is a sound synthesis technique developed by Chowning in the 70s. The technique became popular for the possibilities of generating different timbres with few oscillators. One of the biggest challenges in using FM synthesis is the nonintuitive parameters. It is necessary a profound knowledge of the mathematics behind the synthesis or a vast experience with its operation to create the desired sounds.
A possible solution for this problem is to create a system, which given a sound example, find the synthesis parameters that generates another sound with high perceptual similarity with the sound example. This system would facilitate the sound creation process and would help people with little experience in FM synthesis to understand the relationship between the parameters and the synthesized sound.
This work proposed the creation of a parameter estimation system applied to FM synthesis using the PSO (Particle Swarm Optimization) algorithm.

Key words:
Sound synthesis, Particle swarm optimization, Parameter estimation

Introduction

FM synthesis was developed by Chowning in the 70s[1].It consists in modulating an oscillator's frequency with another oscillator, in a manner that the output signal is in the audible frequency range. One of the challenges in FM synthesis is parameter estimation for a particular sound.
Most of the analysed works approach the parameter estimation problem with genetic algorithms[2,3]. However, there are other works that use different optimization algorithms. The work done by Heise[4] uses a bioinspired metaheuristic algorithm to find audio plugin's parameters that better represent a sound example. The work shows that a bioinspired metaheuristic algorithm achieves good results with audio synthesis parameters estimation.
In this work we proposed an FM parameter estimation method based on PSO (Particle Swarm Optimization). The algorithm was applied in a database created by the FM synthesis system.

Results and Discussion

We created 3 different configurations for the FM synthesis system. The classic configuration with 2 oscillator and 2 ADSR envelopes, in which one oscillator modulates the frequency of the second oscillator. One configuration with 3 oscillator and 3 ADSR envelopes in series, and one configuration with 2 pairs of oscillators and 4 ADSR envelopes in parallel.
The algorithm was tested in databases of 100 audios created with each system configuration using random parameter's values.
As the databases were created with the FM synthesis system we can ensure that the system can generate the sounds present on the database. That way we exclude the doubt that the algorithm can't find the correct parameters because the sound space available to the system doesn't contain the desired sound.
We divided the system in 2 stages for optimization. In the first stage, we fixed all the envelope's parameters in the mean value of the interval and applied the PSO on the oscillator's frequency parameters. In the second stage, we applied the PSO on the envelope's parameters.

Table 1: Number of oscillators in each configuration with error between input and output oscillator's frequency < 1% (input oscillators as reference). (Total: 100 sounds)

FM system	Osc 1	Osc 2	Osc 3	Osc 4
2 oscillators	57	64		
3 oscillators	45	6	11	
4 oscillators	38	11	2	0

Table 2: Mean and standard deviation of minimum squared error between input and output spectra, second stage optimization.

FM system	Mean	Standard deviation
2 oscillators	0.4084	0.3183
3 oscillators	0.6221	0.2614
4 oscillators	0.5377	0.1987

Conclusions

The results show that as the number of oscillators increase it is harder to find the desired sound. This observation is expected, since each extra oscillator brings more parameters and consequently the number of parameter's configurations increases. Also, the optimization algorithm get stuck in local minima, which causes the system not to find the desired sound.

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