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Energy-efficient Real-time Pitch Correction System via FPGA

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The pitch, or in technical terms, the fundamental frequency (the lowest oscillating prominent frequency component of a periodic signal) of a signal, determines how "high" or "low" an audio signal would sound. One can change the pitch of an audio recording by shifting the fundamental frequency of the audio signal, to make sure that the final audio will always stay in tune even if the music performer makes mistakes during the recording process. Such a manner is often referred to as "pitch correction" as a post-processing technique in audio engineering.

Pitch correction, in an offline context, will not be a too challenging task. With the development of computing power, audio analysis and modification seem to become more and more trivial. However, what if one wants to perform pitch correction in real time?

A real-time environment sets harsh timing constraints on the computation. If an algorithm could not be executed efficiently enough, the timing requirement would then not be met. What's more, a more limited computation time usually calls for a more powerful computing system. Indeed, computing power is becoming more and more abundant as the technology evolves. Yet, in certain circumstances where a powerful computing system cannot be deployed, an energy-efficient solution becomes vital.

Back to the previous question. If one needs to perform pitch correction, a pitch detection operation needs to be performed first, followed by a pitch shift operation. The pitch detection part tells us where is the current pitch and how far it is away from the designated target, and the pitch shift part modifies the pitch to the desired level. There exist numerous studies with different approaches aimed to perform the prior two tasks. Nonetheless, little research has been conducted to look for an energy-efficient real-time solution that solves both questions.

Thus, this thesis study aims to develop a standalone power-efficient system that can perform pitch detection and pitch shift operation simultaneously in real-time. The processing needs to be fast enough to catch up with the audio sampling frequency, meanwhile utilizing as few hardware resources as possible. In this thesis study, we proposed and developed two novel mechanisms, one being the auto-cross correlation that performs pitch detection, and another being a ring buffer, with jump-based-on-pitch pointers, that performs pitch shift operation. We then verified our approaches via experiments, making sure that they could yield an as-expected result. After the verification process, we implemented our design on an FPGA platform. After the implementation, we recorded the output generated by our new design and verified that the new design is able to satisfy the requirements set by this study.