Embedded Systems Final Project Proposal

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OVERVIEW

For our final project in this class, we would like to create a machine that involves manipulation of the FPGA display as well as signal processing of a real instrument hooked to a microphone.

These two components will interact as follows: on the FPGA display will be a Guitar Hero-esque simulation. There will be blocks of four different colors that each correspond to a different range of frequencies. These blocks will slowly cascade down the screen (like Tetris). At the bottom of the screen is a green bar, and when a block enters this green area the user will be expected to create a noise of the appropriate frequency on a “clean” harmonic instrument like a xylophone.

This is where the other major component of the project comes into play: in front of the user will be an instrument that can produce four distinct sounds, each corresponding to the expected frequency range of each block. When a colored block enters the green area on the FPGA, the user should play the instrument in such a way that the correct note is produced. If this is done in the correct time frame, the user gets a “point” that will be displayed on the game interface. Real time note recognition will be key so implementing a custom hardware FFT will be important in accelerating the process.

ALTERNATE IDEAS

There are several possible alternatives we could implement in the case of something going wrong with our initial idea, e.g. an FFT becoming infeasible to do on the FPGA, or the instrument is not capable of producing 4 distinct enough tones.

One of these possibilities would be to have four buttons producing different tones, in the hope that it would be easier for the microphone to distinguish between the tones if they are computer-generated. The other possibility would be to send the signals that the buttons produce directly to the FPGA, but since no ADC processing is required in this approach it would be a last resort.

PARTS LIST

- FPGA Altera Cyclone V
- VGA Monitor
- Instrument Possibilities:
    - Toy Piano
    - Xylophone - plastic
    - Xylophone - wooden
    - Recorder
- Microphone - directional for noise mitigation

HARDWARE

- We will probably use a time-signal from the directional microphone and pipeline it to the FPGA which will calculate a time short-time fourier transform. The STFT is many FFTs in parallel which can be implemented using SystemVerilog. There is probably no need to store the signal information in memory because we would aim to hot code the output of the STFT and note recognition algorithm for each of the four desired notes.
- Track whether the correct note is played at the correct time
- Displaying the target notes on the screen as colored rectangles, a green “valid” region on the bottom, and a score in the top corner

SOFTWARE

- Keeping track of game state (ex: time, score, what song is playing)
- Pause/restart functionality
- Menu for song selection

POSSIBLE MILESTONES

- ASAP: Get frequency output from each instrument on Audacity or MATLAB and decide on a final instrument to use
- Implement FFT on the FPGA
- Implement Audio Interfacing on the FPGA board, use FFT and other filters to detect a tone.
- Use the detected tones and have the game interact with the played note
    - Ensure the FPGA can determine which note of the 4 is being played
- Develop the display of the game which includes moving notes, point counter and detection animation.

REFERENCES:

Implementing FFT on FPGA : https://www.youtube.com/watch?v=BtTNeQszSJo&t=2924s

TNShazam Report from Embedded Systems 2019:
http://www.cs.columbia.edu/~sedwards/classes/2019/4840-spring/reports/TNShazam.pdf