Project Proposal: FPGA Acceleration of Computer-Simulated Water Physics

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Figure 1: Actual Visualization of Our Final Product (100% Real)

Project Overview

- The focus of this project will be to implement a hardware acceleration of the algorithm for computer-simulated liquid physics. Our implementation will be in the form of a water bottle displayed on a VGA that will respond to outside input from keyboard and mouse. It will move, rotate, shake etc. and the liquid inside will respond in real time. For example, if the left button on the keyboard is held, the bottle will move left, and the water will respond accordingly. We have preliminary research on appropriate water physics equations, such as applying Navier-Stokes fluid equations [1] [2]. Another goal is for the water bottle to move with the mouse in real time.

Design Outline

- FPGA (SystemVerilog):
    - Liquid Physics algorithm
    - Keyboard and mouse I/O
    - Vertex rendering and complete graphics pipeline through OpenGL software (Fig 2) [3]

- Computer (C/C++):
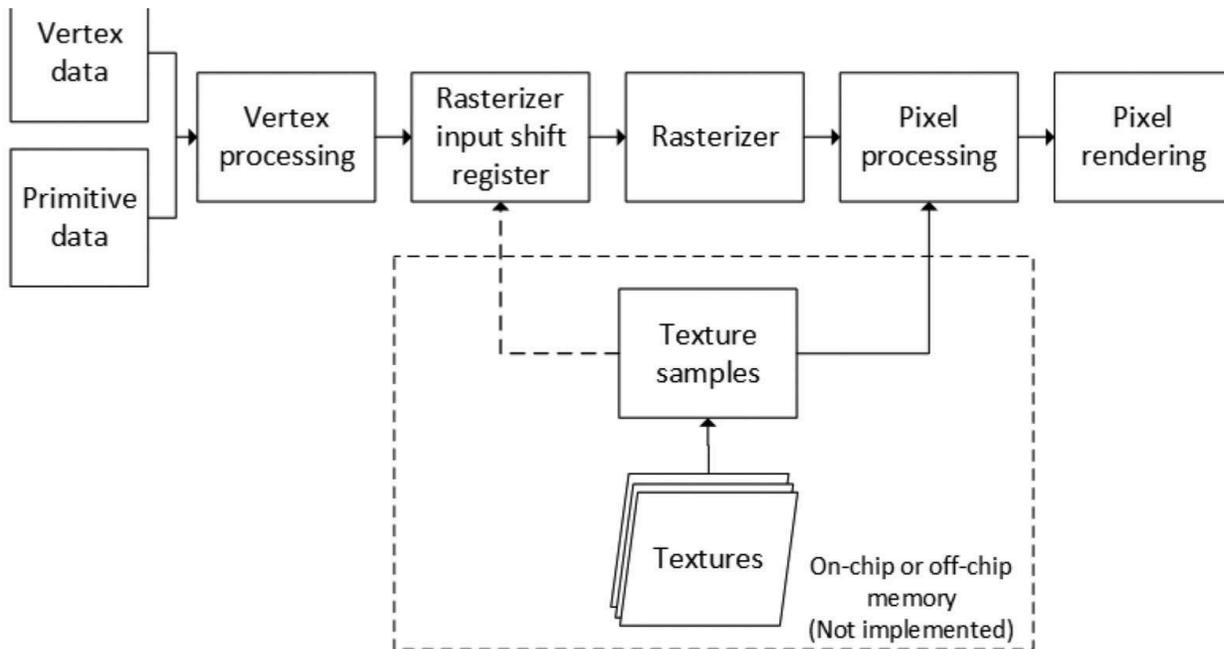   - VGA rendering
    - UI

Figure 2: graphics pipeline for the FPGA-SoC

I/O Device
- Video Output: VGA
- Controller Input: Keyboard, Mouse, Gyroscope

Milestone and Plan
- Set up the VGA output to display
- Convert the input information (keyboard, mouse, or Gyroscope), which contains movement
- Implement an algorithm for computer-generated liquid physics in C/C++, which calculates the vertex
- Implement the massive computation part of the algorithm in SystemVerilog to accelerate on an FPGA
- Implement the complete graphics pipeline using OpenGL software

References

[1] J. Stam, *Real-Time Fluid Dynamics for Games*.
https://graphics.cs.cmu.edu/nsp/course/15-464/Fall09/papers/StamFluidforGames.pdf
[2] A. Wesley, *GPU Gems*. Part 1, Chapter 1. NVIDIA, 2004.
https://developer.nvidia.com/gpugems/gpugems/contributors

[3] Beasley , A.E., Clarke , C.T. and Watson, R.J. (2020) *An OpenGL Compliant Hardware Implementation of a Graphic Processing Unit Using Field Programmable Gate Array–System on Chip Technology*, *Acm digital library* . Available at: https://dl.acm.org/doi/10.1145/3410357.