Reconfigurable Point Based 3-D Graphics Rendering on FPGA

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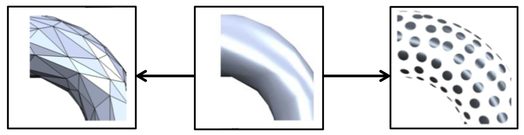
The problem

- Triangle meshes are dominant primitives in graphics processing.
- Complex 3D object models with triangles meshes are expensive to store and process
- With millions of triangle meshes, meshes that are smaller than a pixel do not get displayed on the screen
- Complex model demands faster processing and efficient storage

Point based rendering

- Represent 3D objects using points rather than triangle meshes
- Point has location, normal, color, alpha etc. information
- Conceptually simpler than triangle meshes
- Flexible and scalable processing possible
- No connectivity information => lesser demands on storage



Mesh Rendendering *Sample* *Point Rendendering*

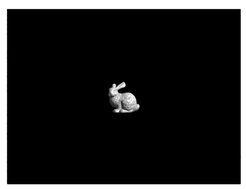
Proposal

We propose a reconfigurable direct 3D point based rendering system.

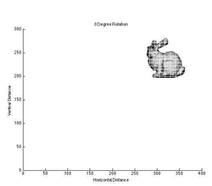
- System should be able to programmable
- 60 fps frame rate
- Double buffering
- 18 bit color
- Modular design approach targeting Xilinx ML505 evaluation platform

High Level Modeling

- OpenGL model gives high level overview of operations involved
- Not much insight into hardware operation
- MATLAB is closer to hardware operations

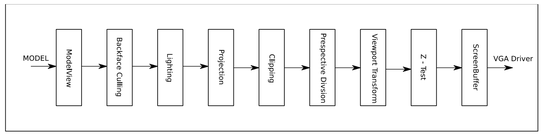


OpenGL model



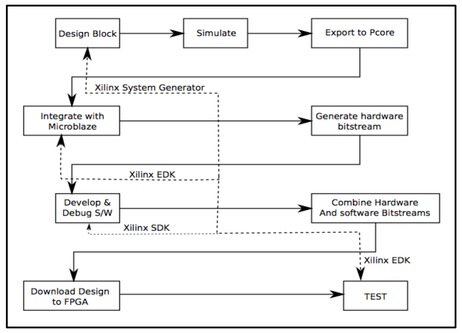
MATLAB model

Point based rendering pipeline

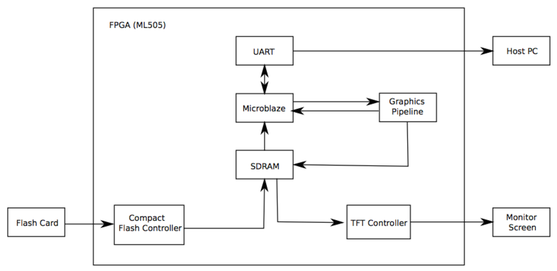


- Determine operations and optimizations involved in each stage
- Decide hardware/software implementation
- Figure out control mechanism and implementation strategy
- Prepare test plan for block level and system level design

Implementation process

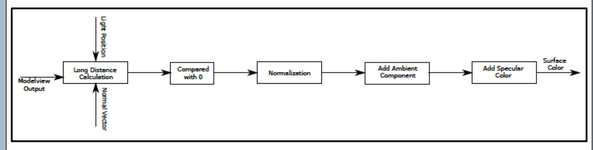


Hardware



- Design using available Xilinx IPs
- Microblaze processor is central control processor
- On board SDRAM is used as frame buffer and z buffer
- UART for debug
- Rendering pipeline attached as slave to peripheral bus
- Vertex, normal and color data stored on Compact Flash card
- Hardware reconfigurability achieved by storing different designs as different bitstreams.

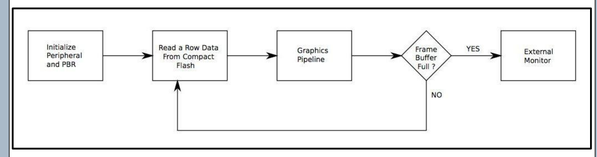
Color pipeline



Phong Shading implemented in hardware

- Square root required for normalization approximated to less than 10% error in about 5 clocks
- Specular component stored as lookup table
- Diffuse component calculated in hardware

Software



- Lightweight standalone OS provided by Xilinx run on Microblaze
- Software initializes, configures, monitors and manipulates hardware
- Modelview operation in software to reduce design size
- Built in drivers for peripherals used to reduce time and effort in writing drivers

Testing and Results

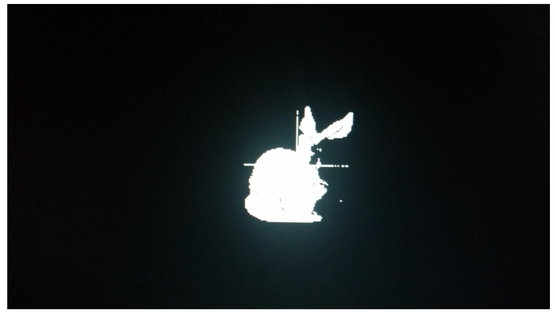


Figure 4: FPGA rendering of point model

- Individual blocks tested with UART
- Incremental test strategy followed to allow easy debug
- Rendering pipeline tested using software accessible registers
- 1,00,000 point model rendered at 60 fps
- Hardware uses about 60% of FPGA resources

Takeaways

- Use of existing IPs reduces design turn around time, improves modularity.
- Reconfigurable design increases flexibility and scalability.
- Can complement existing mesh based rendering techniques
- Design has room to incorporate complex point rendering algorithms and reconfiguration options

Principal Contributions

- Hardware/Software co-design framework for the design of reconfigurable PBR architecture
- Design and implementation of a hardware architecture for PBR targeted towards an FPGA implementation
- Modeling and verification of PBR in MATLAB and OpenGL

References

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The team

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