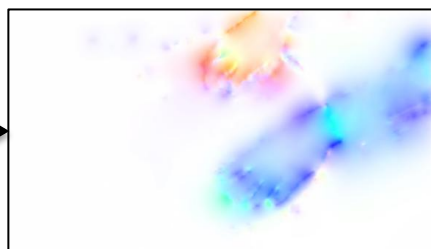# Virtual Musical Instrument Integrated Demo

Michael Anderson, Grey Ballard, Sarah Bird, Gage Eads, Yunsup Lee, Ian Saxton, David Sheffield, Andrew Waterman, David Wessel

ParLab Final Party

May 30th 2013

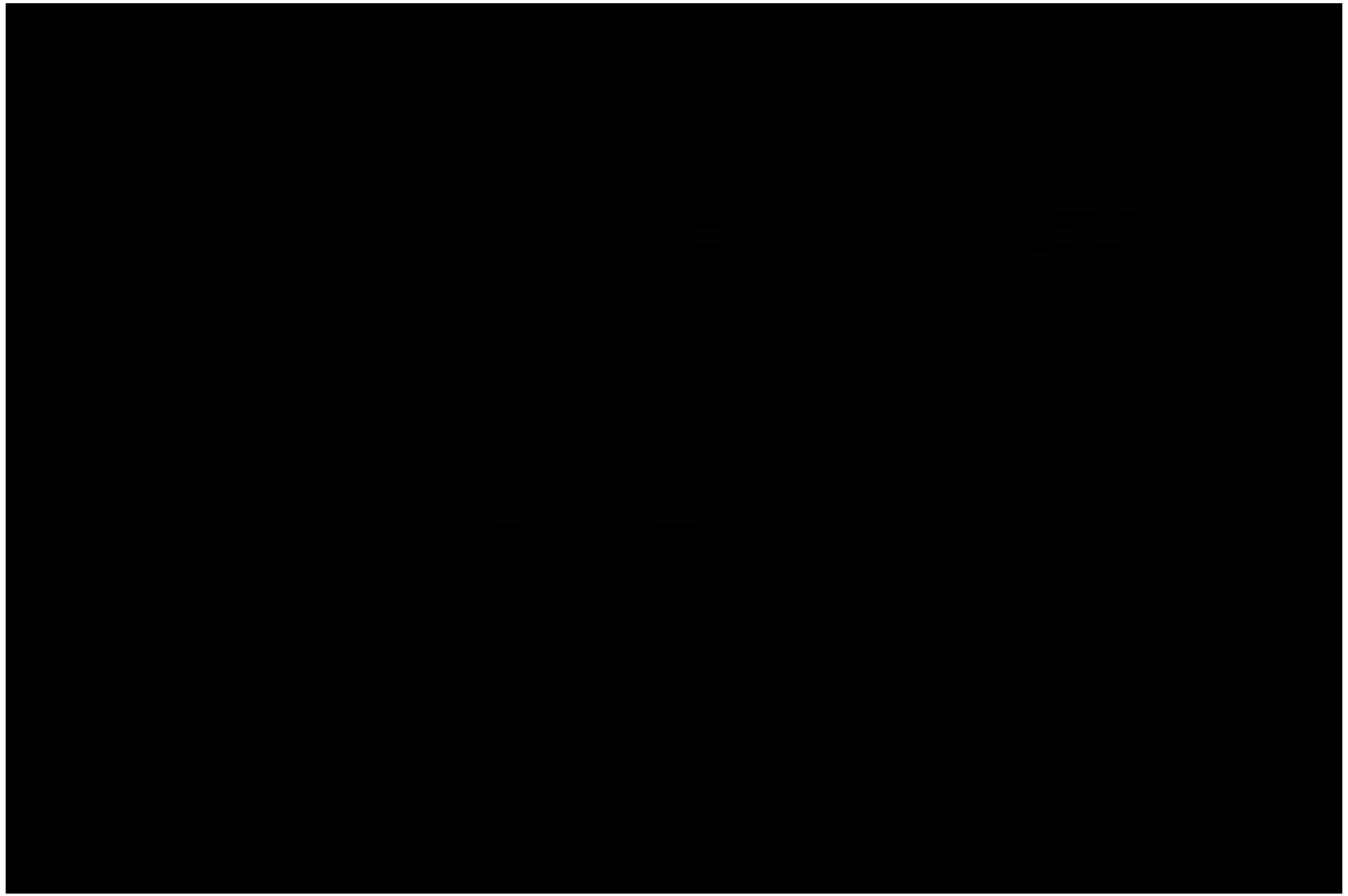# Demo Overview



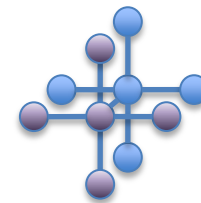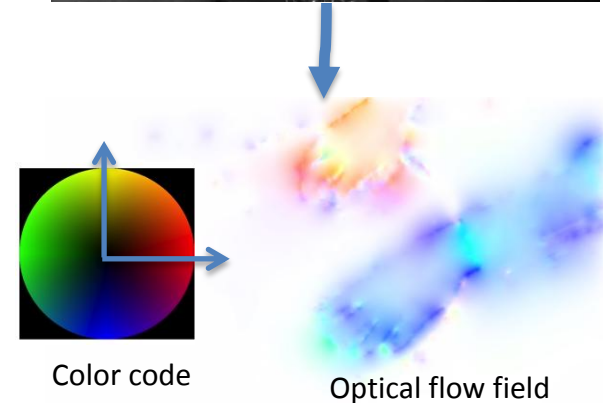Live video capture      Computed motion      Synthesized Audio

- ❖ Vision-based virtual music instrument
  - ▪ Synthesizing audio from hand motions over a drum
- ❖ Demonstrates ParLab technology working together:
  - ▪ SEJITS
  - ▪ Tessellation
  - ▪ RISC-V
  - ▪ Communication-avoiding algorithms
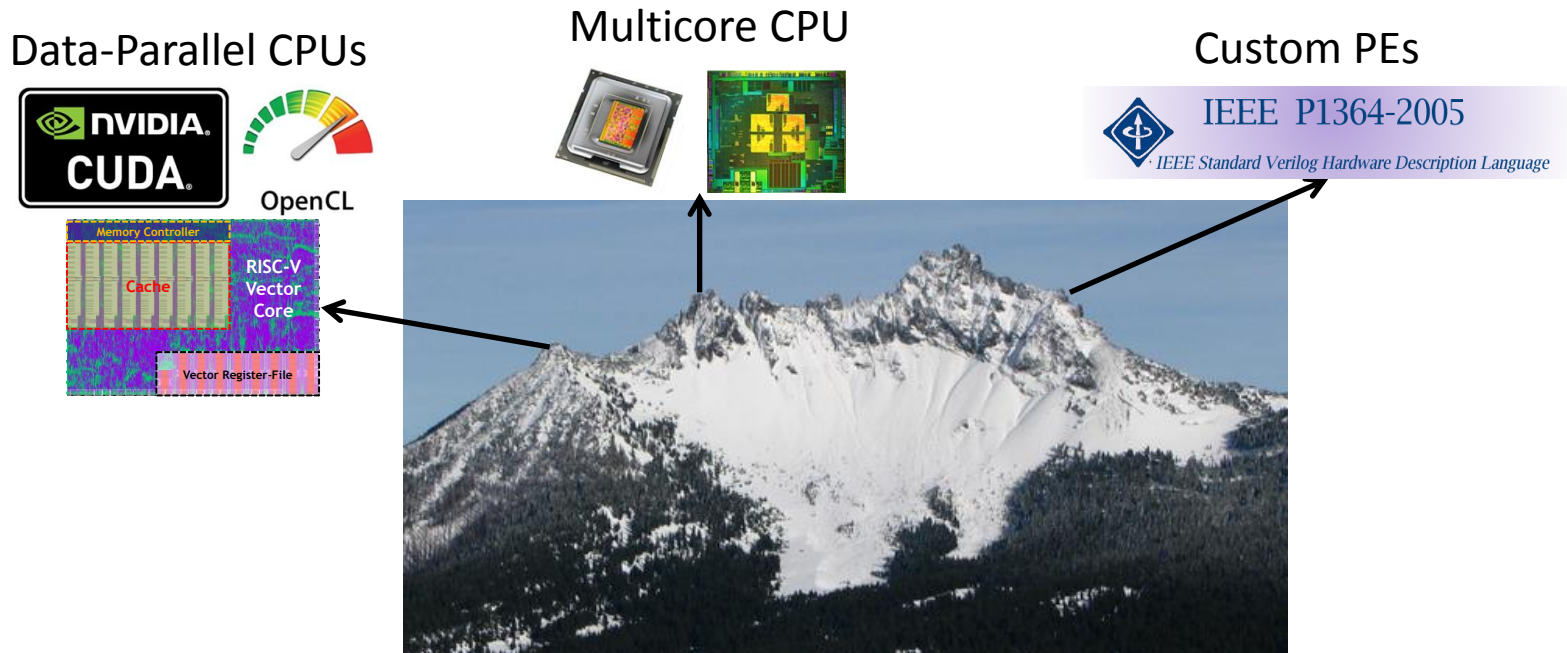  - ▪ Parallel computer vision
  - ▪ Audio graph signal processing

# Optical Flow

- Optical flow computes the **apparent motion** of each pixel (direction and speed) across two frames of a video

- We solve optical flow using the Horn-Schunck method

- Inner loop is a sparse linear solve with 2 coupled 5-point stencils

- We can solve the linear system using **communication-avoiding conjugate gradient (CA-CG)**

- We demonstrate two versions:
  - CA-CG in OpenCL (Native GPU code)
  - CG in Three Fingered Jack (SEJITS vectorizing compiler)



Color code

Optical flow field



Structure of optical flow sparse matrix

# Three Fingered Jack

Data-Parallel CPUs

**nvidia CUDA**

OpenCL

Memory Controller

Cache

RISC-V Vector Core

Vector Register-File

Multicore CPU

Custom PEs

IEEE  P1364-2005

*IEEE Standard Verilog Hardware Description Language*

## Three Fingered Jack

– Three Fingered Jack is a Python-based SEJITS framework to generate code for data-parallel and many-core CPUs along with generating custom processing engine implementations

  – Parallelism extracted using reordering transforms

– We use TFJ to target SSE on Tessellation and the vector unit on RISC-V Hwacha (UC Berkeley test chip)
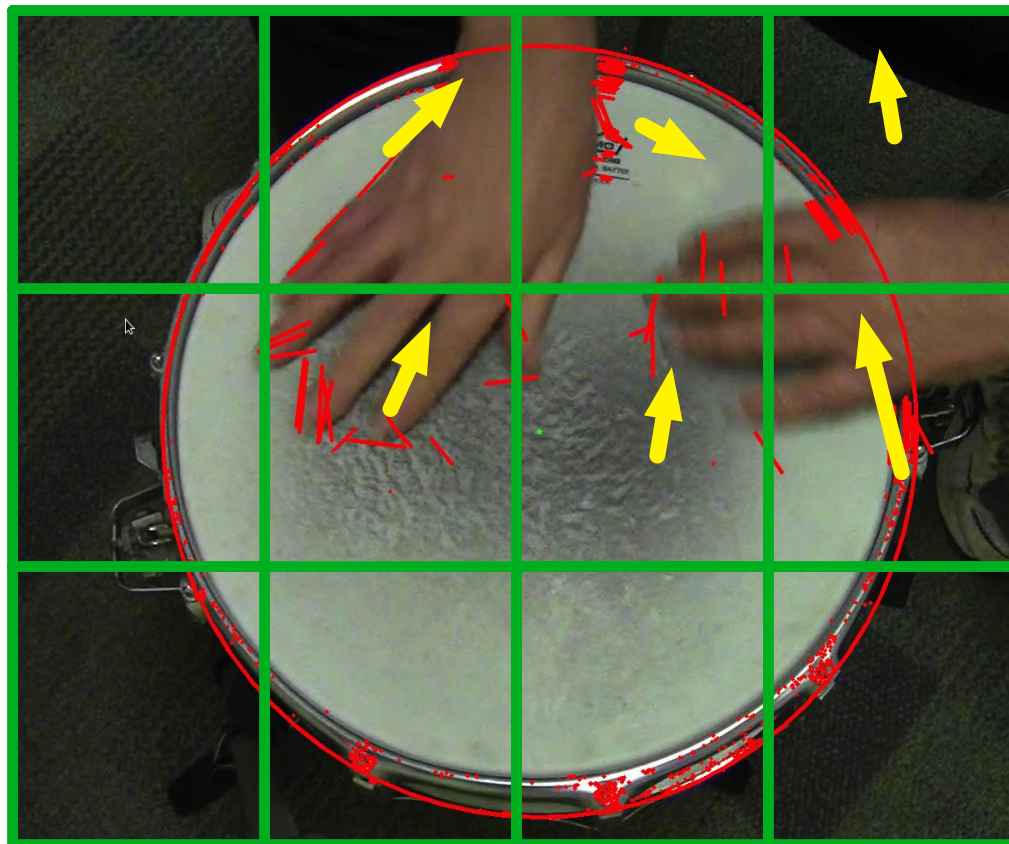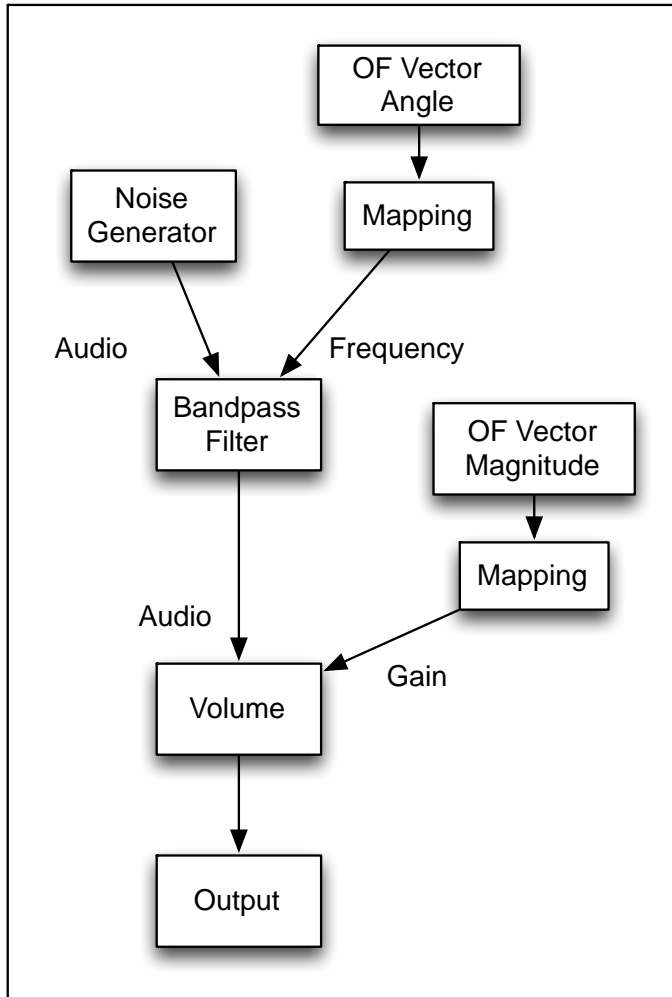
Faust Source Code:
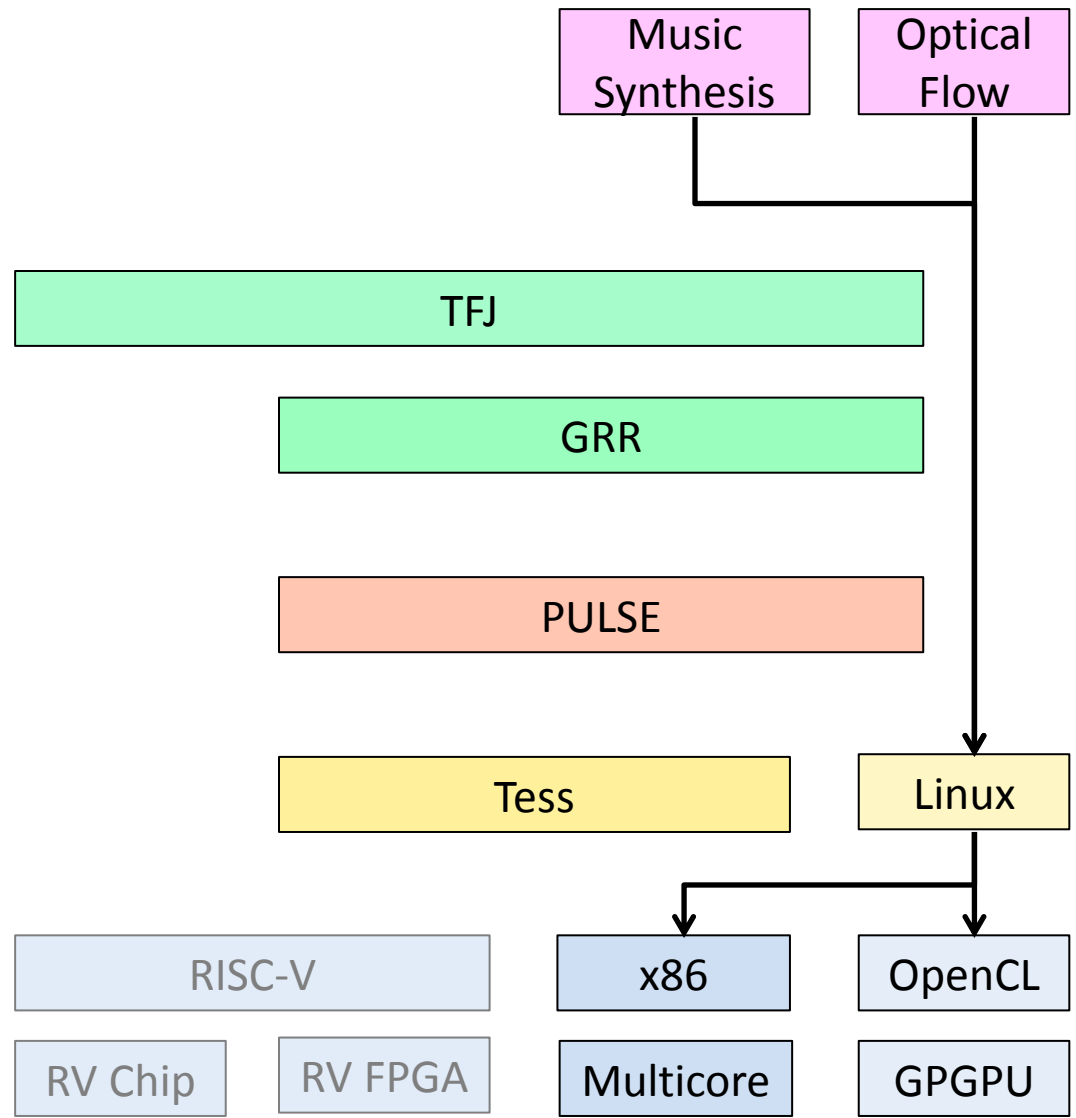
```
import("music.lib");
import("filter.lib");

pitch_param = hslider("pitch", 60, 0, 128, 0.00001);
gain_param = hslider("gain", 0, -128, 0, 0.00001);
pitch = smooth(0.9995, pitch_param);
gain = smooth(0.9995, gain_param);

pitch_to_freq(pitch) = 440.0 * pow(2.0, (pitch - 69.0) / 12.0);

process =
        db2linear(gain) * noise :
        resonbp(pitch_to_freq(pitch), 30.0, 1.0);
```
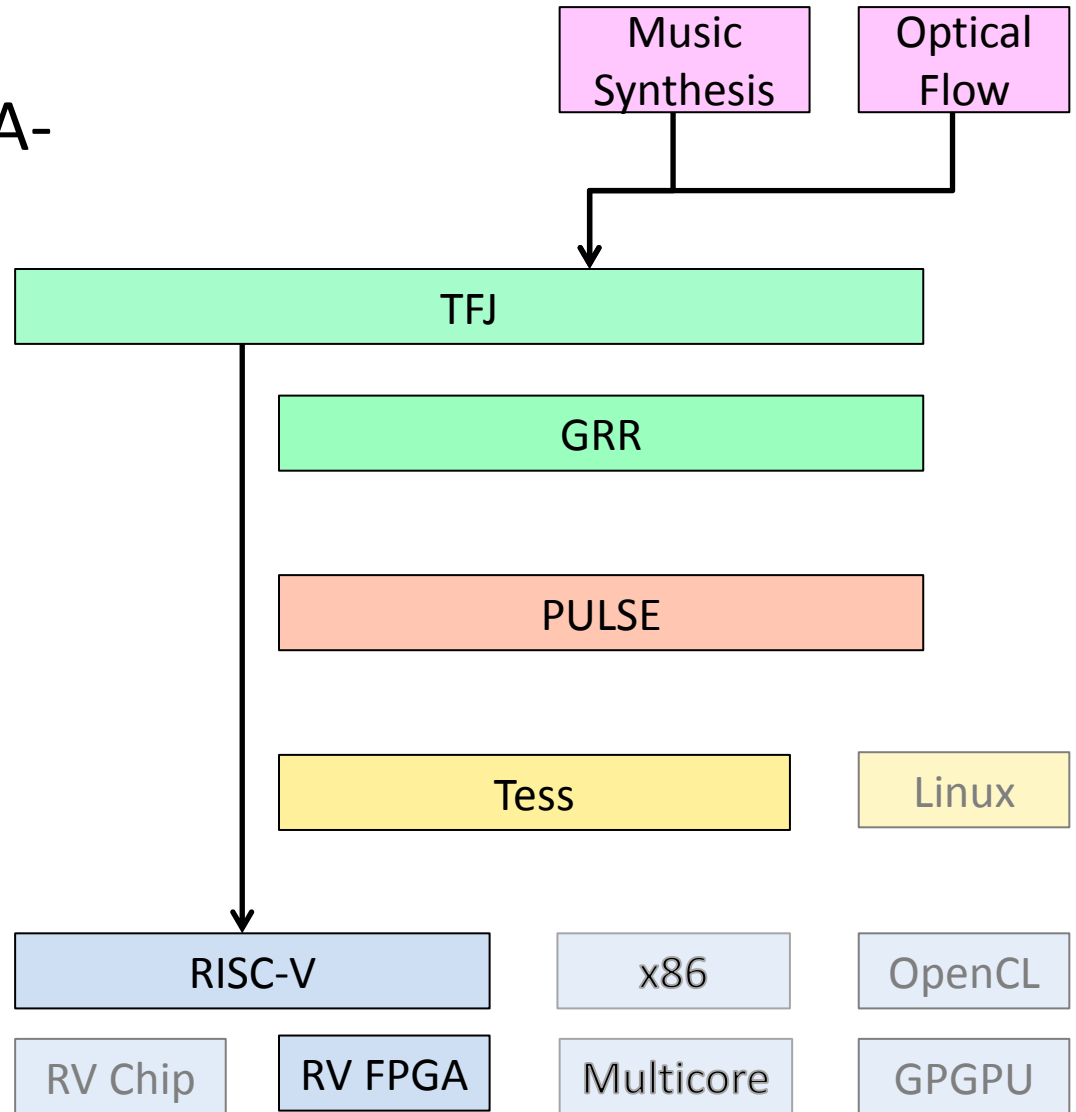
# Our Configurations

- Linux with NVIDIA GPU



Music Synthesis

Optical Flow

TFJ

GRR

PULSE

Tess

Linux

RISC-V

x86

OpenCL

RV Chip

RV FPGA

Multicore

GPGPU

Linux Configuration

# Our Configurations

- Tessellation on FPGA-simulated RISC-V

- Three Fingered Jack offline assembly-code generation

| Music Synthesis | Optical Flow |
| --- | --- |

TFJ

GRR

PULSE

| Tess | Linux |

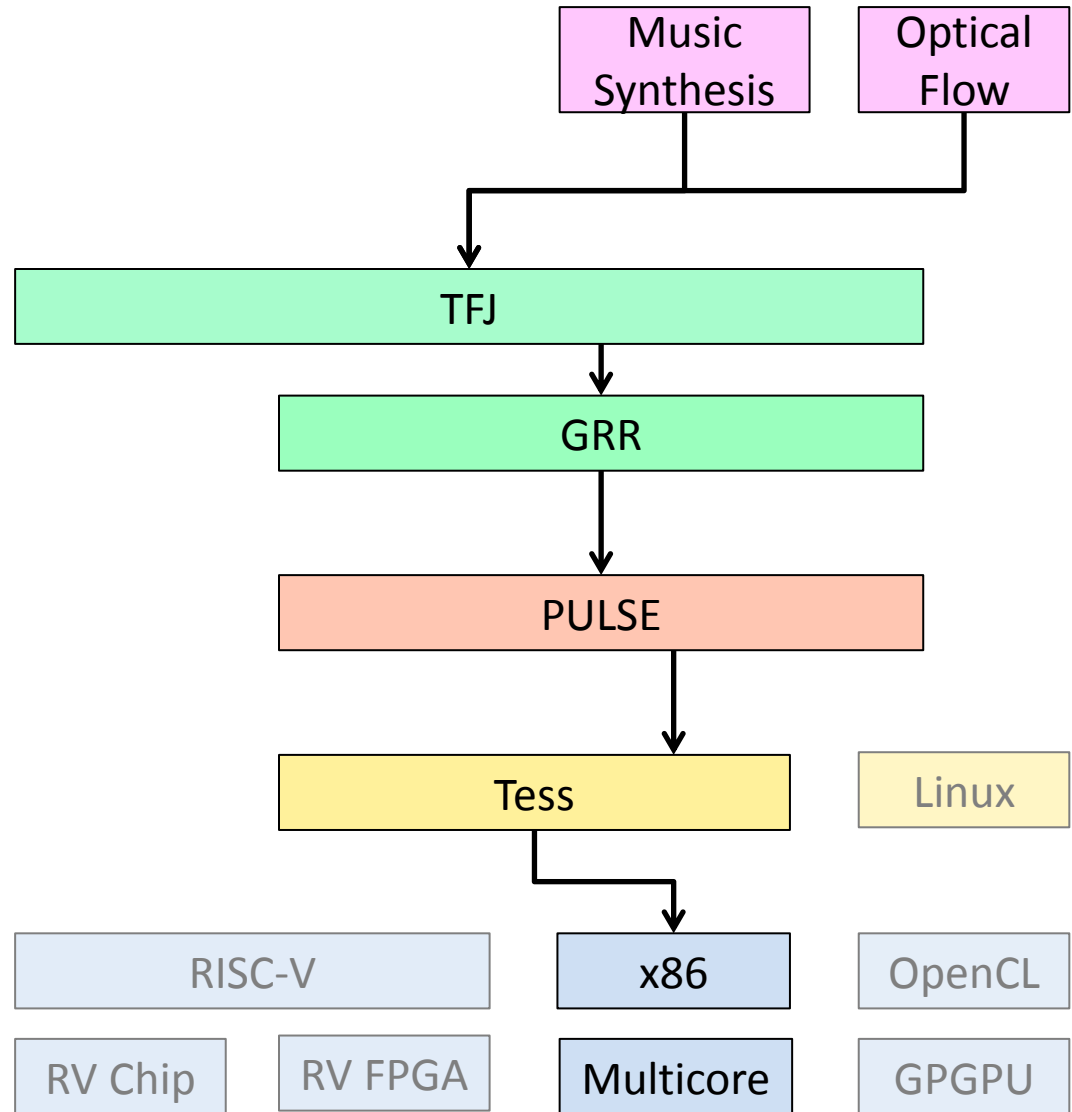| RISC-V | x86 | OpenCL |

| RV Chip | RV FPGA | Multicore | GPGPU |

Tessellation on RV FPGA configuration

9

- EOS14 (RISC-V chip)

- Three Fingered Jack offline assembly-code generation

| Music Synthesis | Optical Flow |
|---|---|

TFJ

GRR

PULSE

| Tess | Linux |
|---|---|

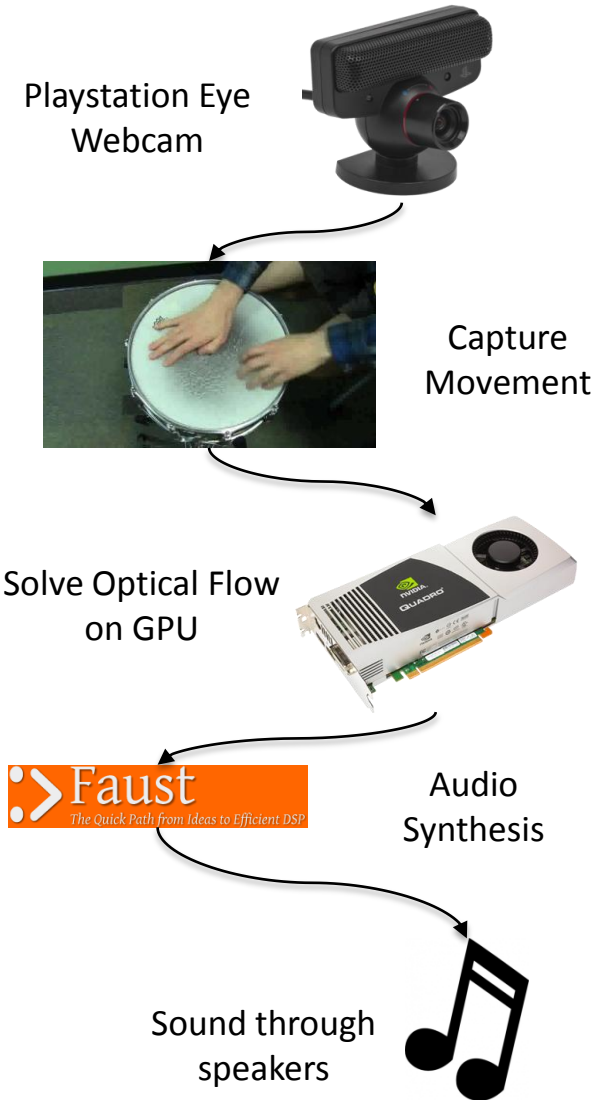| RISC-V | x86 | OpenCL |
|---|---|---|

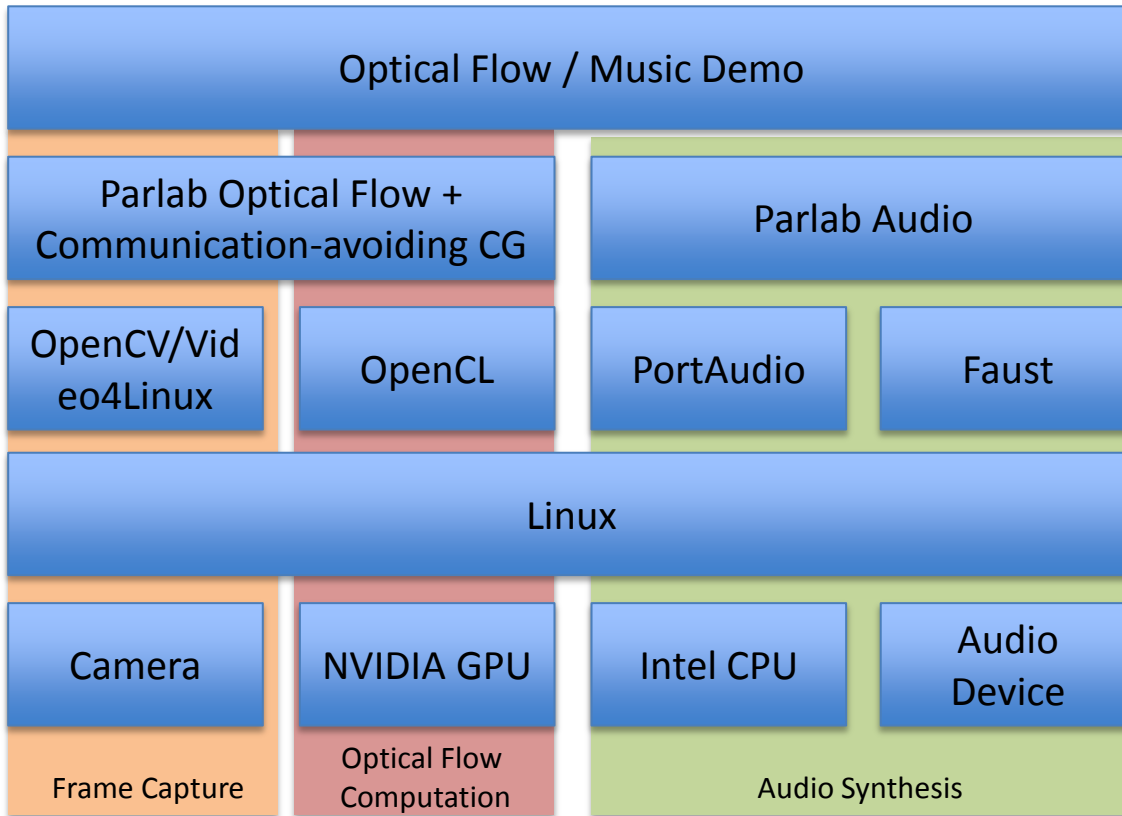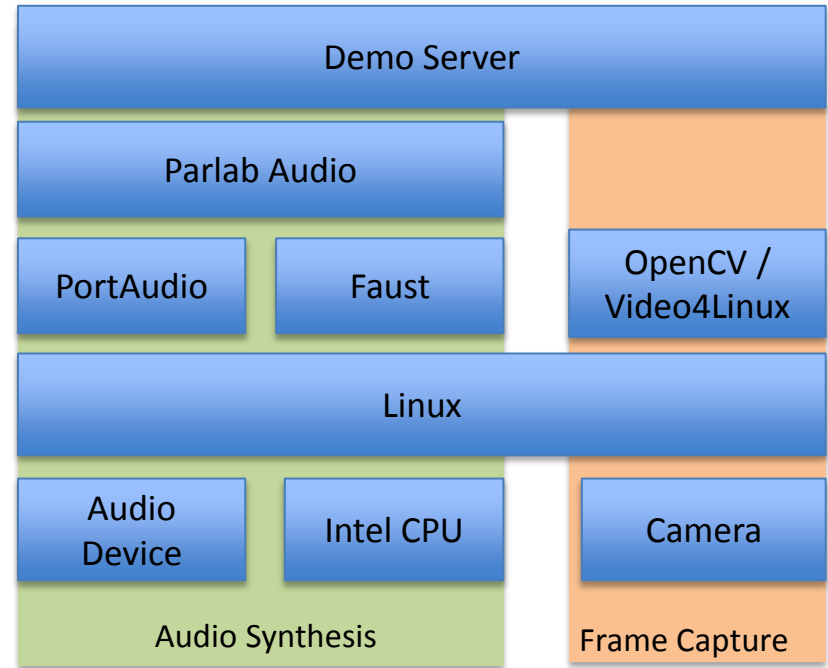| RV Chip | RV FPGA | Multicore | GPGPU |
|---|---|---|---|
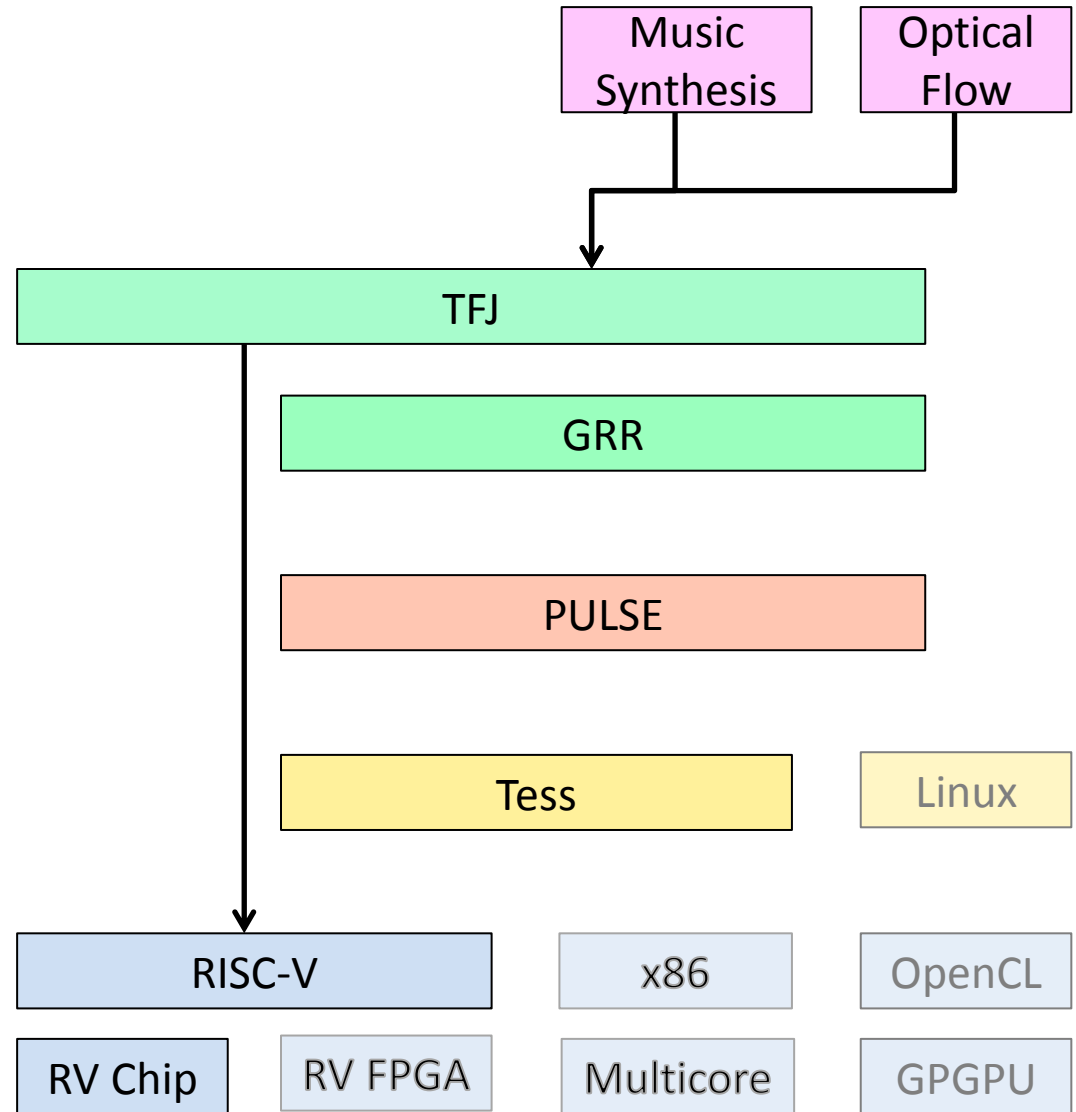
EOS14 (RISC-V chip) configuration

- Tessellation on x86
- Three Fingered Jack offline source-to-source translation



Tessellation on x86 Configuration

# Linux Configuration

EECS
Electrical Engineering and
Computer Sciences

BERKELEY PAR LAB

## Optical Flow / Music Demo

| Parlab Optical Flow + Communication-avoiding CG | | Parlab Audio | |
| OpenCV/Video4Linux | OpenCL | PortAudio | Faust |

### Linux

| Camera | NVIDIA GPU | Intel CPU | Audio Device |
| Frame Capture | Optical Flow Computation | Audio Synthesis | |

Playstation Eye Webcam

Capture Movement

Solve Optical Flow on GPU

nvidia QUADRO

> Faust
The Quick Path from Ideas to Efficient DSP

Audio Synthesis

Sound through speakers

# Tessellation on FPGA-simulated RISC-V Configuration

FPGA Demo Client

Parlab Optical Flow

TFJ (Offline)

Tessellation

FPGA

Optical Flow Computation

Demo Server

Parlab Audio

PortAudio

Faust

OpenCV / Video4Linux

Linux

Audio Device

Intel CPU

Camera

Audio Synthesis

Frame Capture
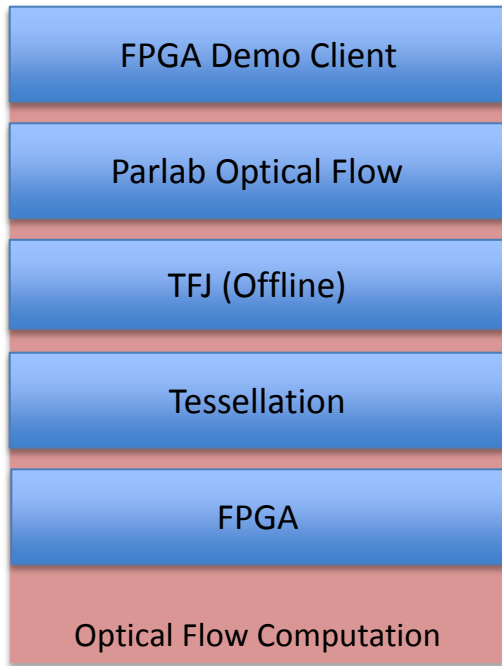
Zynq FPGA SoC

Demo Server

PlayStation Eye Webcam

# Tessellation on RISC-V Chip

# Tessellation on x86 Configuration

Demo Client
- Parlab Optical Flow
- TFJ (Offline)
- Parlab Audio
  - PortAudio
  - Faust
- Tessellation
- Intel CPU
- NIC
- Audio Device
- Optical Flow Computation
- Audio Synthesis

Frame Data

Demo Server
- OpenCV / Video4Linux
- Linux
- NIC
- Intel CPU
- Camera
- Frame Capture

Demo Client — Ethernet Switch — Demo Server — PlayStation Eye Webcam