ECE532: Digital Systems Design

Turretmaster 5000

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Background and Motivation

Inspiration

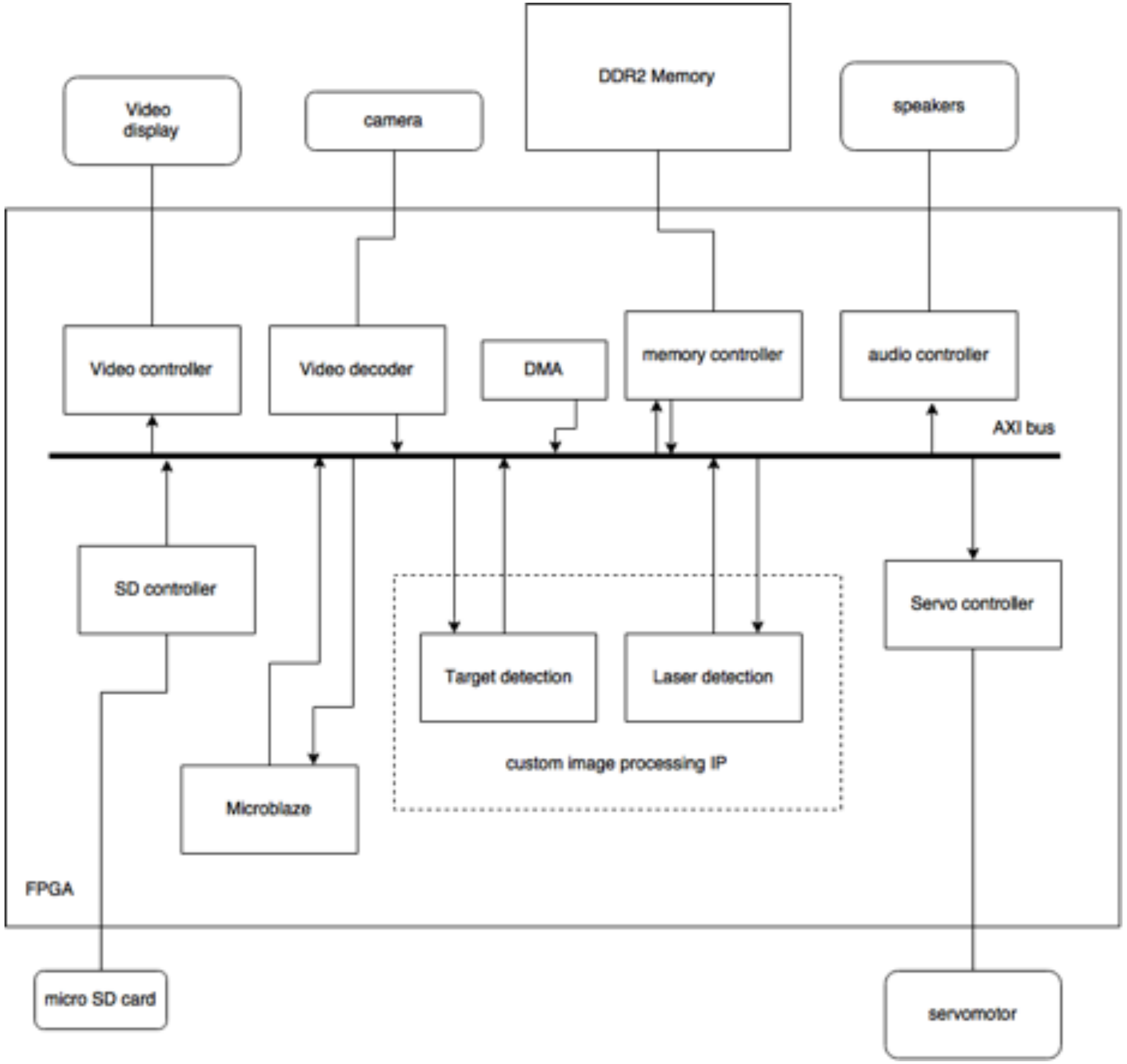
- Automated turrets are common in games
  - Portal
  - Team Fortress 2
- Automatically detect enemies, fire at them

Practical Applications

- Shotgun microphone aiming
- Security cameras
- Military applications

Initial Goals

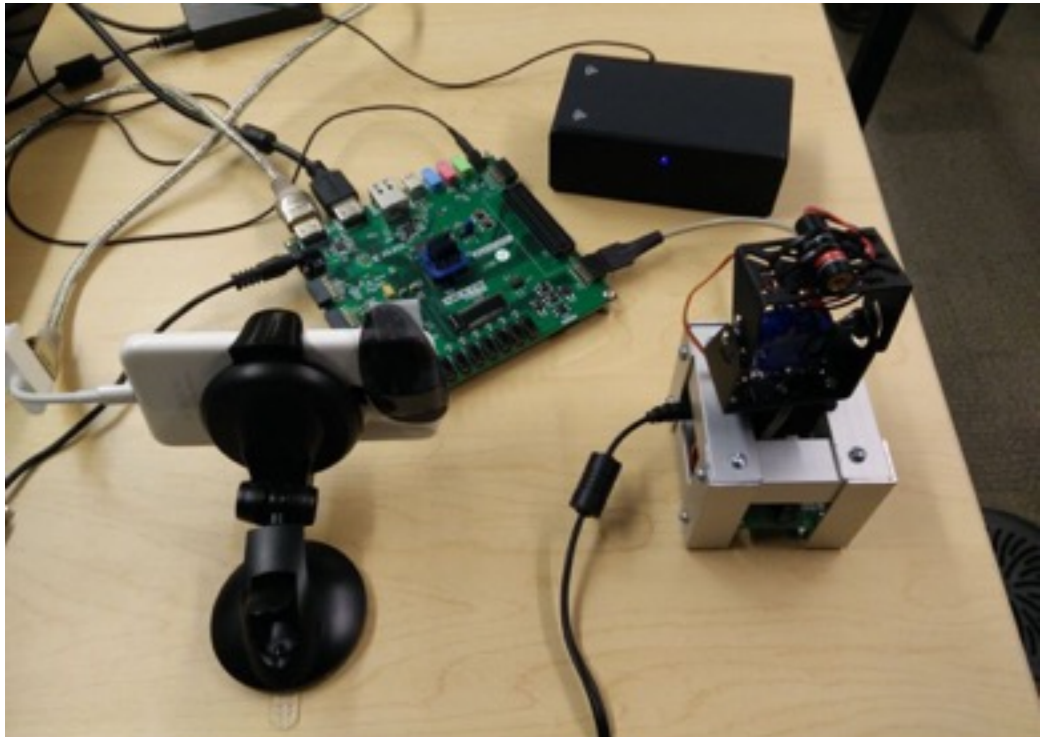
- Identify and differentiate between different targets on a video feed
- Be able to react to target motions
- Be able to “fire upon” target when a lock-on is achieved
  - play a sound

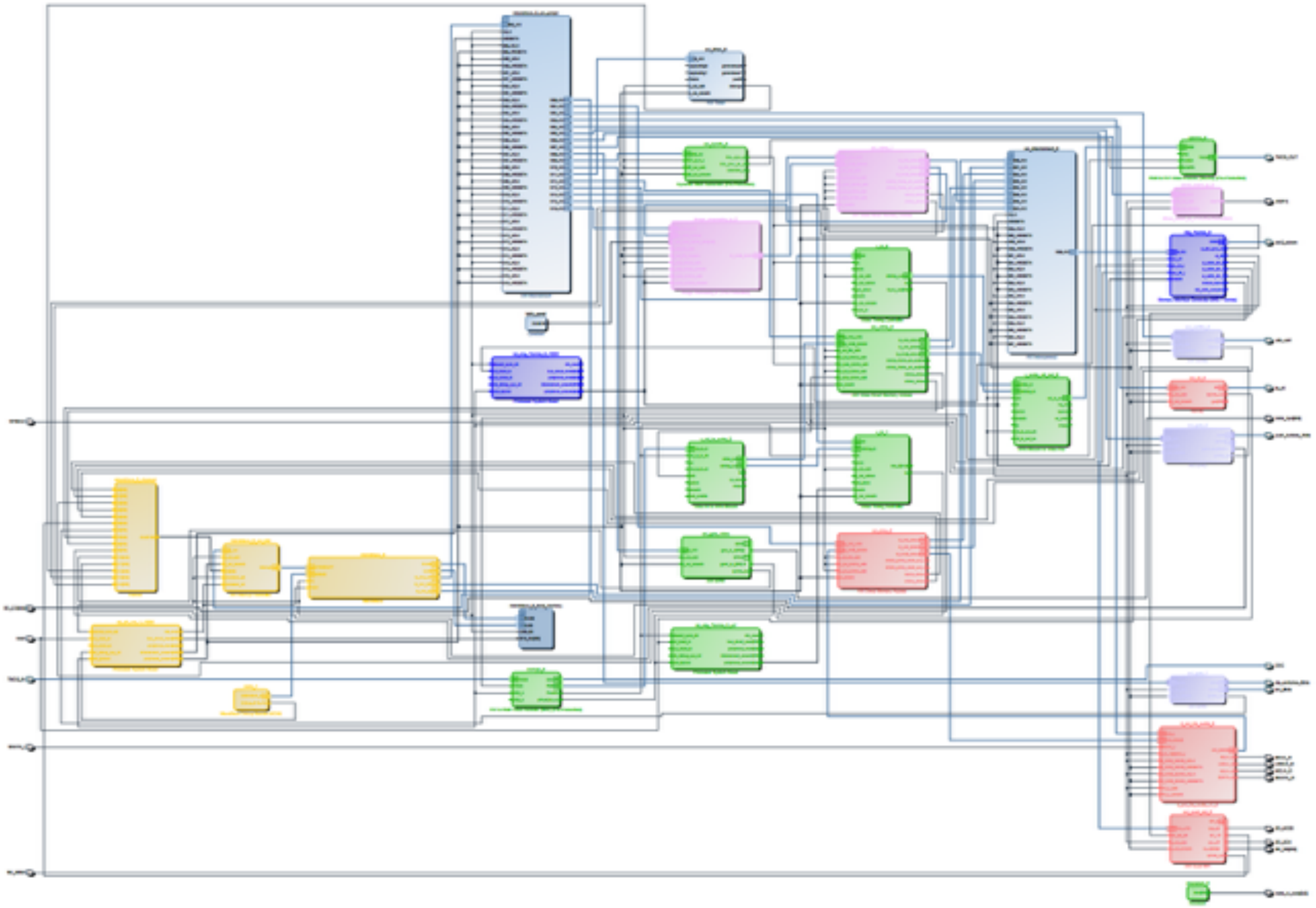

Video display
camera
DDR2 Memory
speakers
Video controller
Video decoder
DMA
memory controller
audio controller
AXI bus
SD controller
Target detection
Laser detection
Servo controller
custom image processing IP
Microblaze
FPGA
micro SD card
servomotor

Our Final Design

Peripherals and Physical Components

- Laser turret
  - Pan/tilt bracket
  - 2 servo motors
  - Laser diode
  - Control circuitry
- Camera
- Monitor
- Speakers
- SD card
- Nexys Video Board





Video
Microblaze
Custom IP
Memory
Audio
Debug
Interconnect

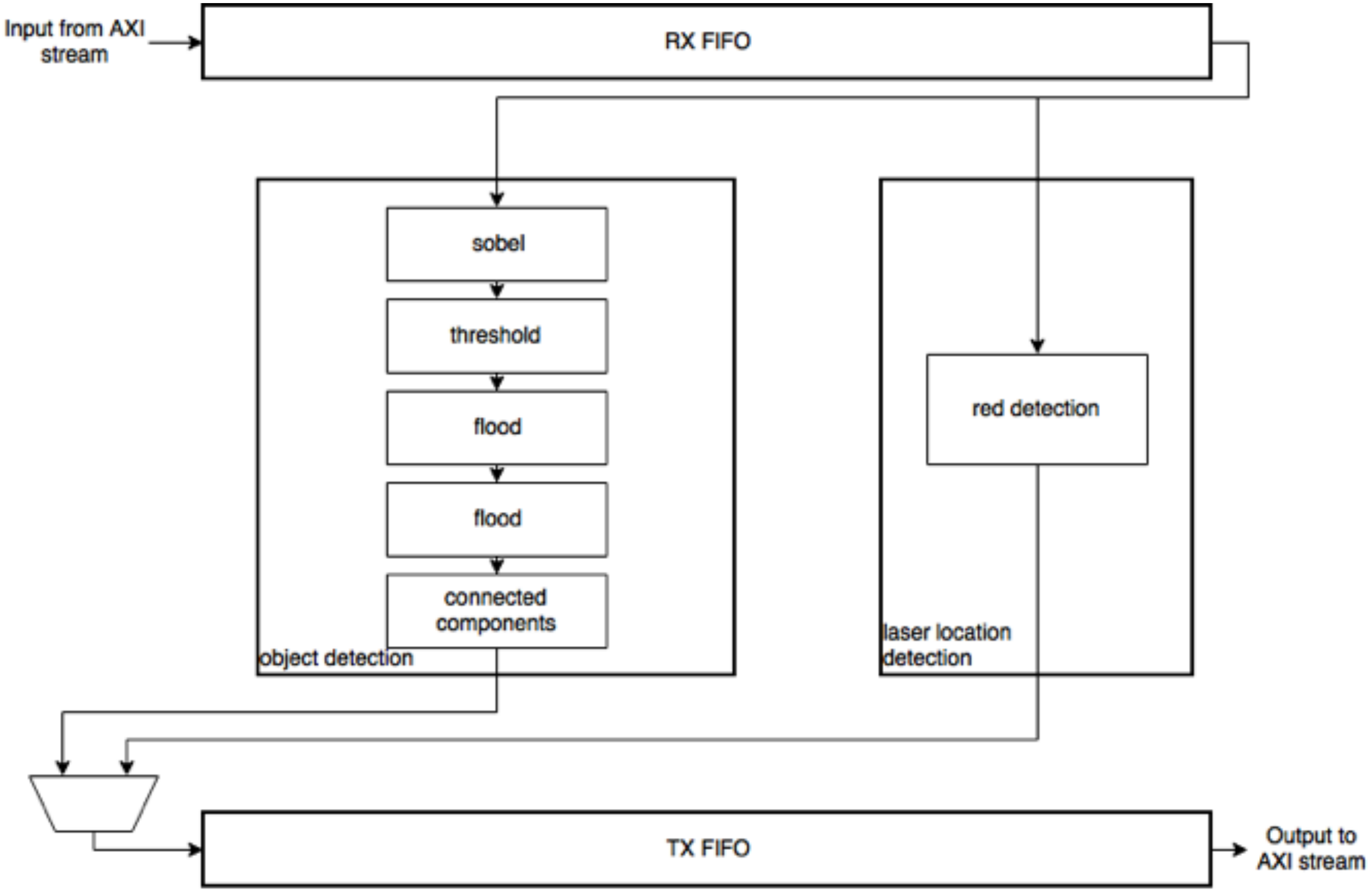
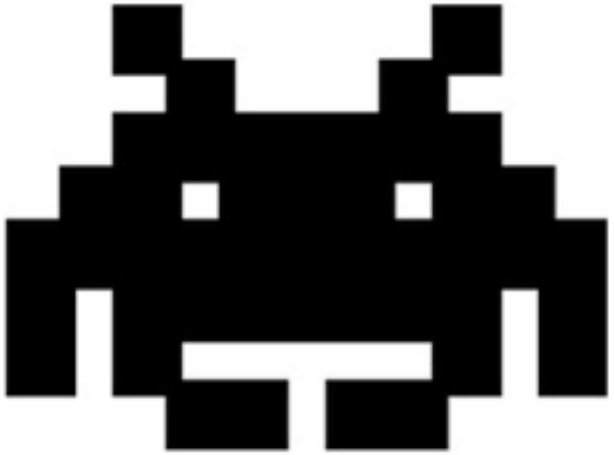
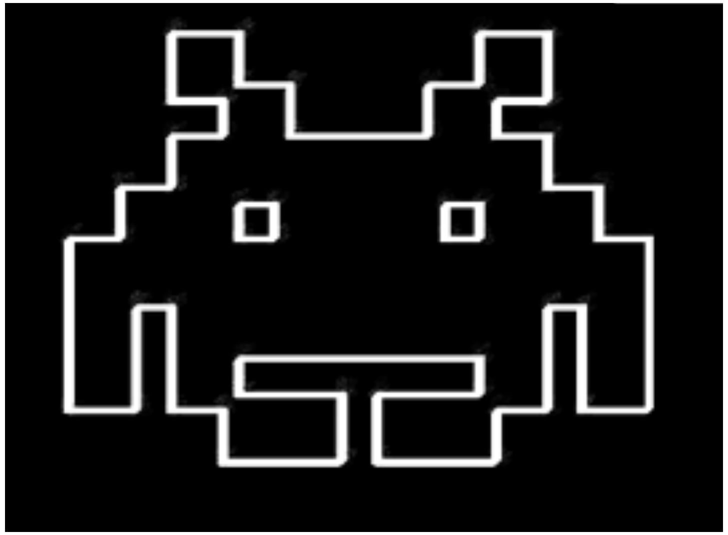

Input from AXI stream
RX FIFO
sobel
threshold
flood
flood
connected components
object detection
red detection
laser location detection
TX FIFO
Output to AXI stream

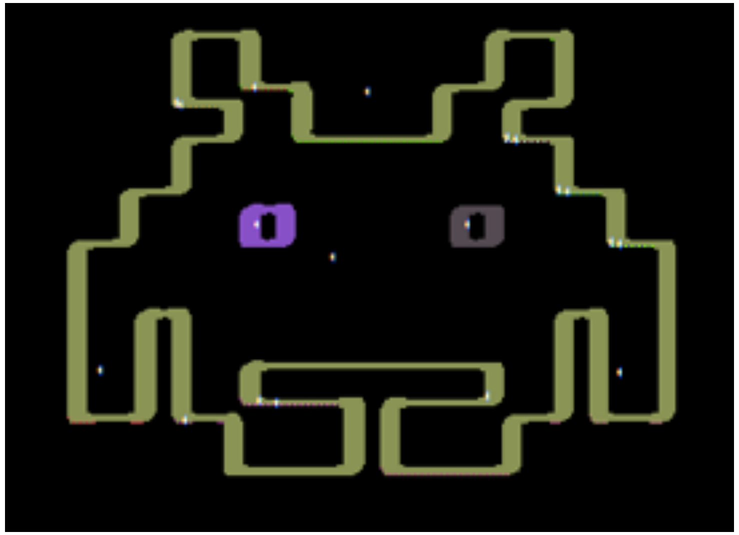
Image Processing Stages



Input Image



Sobel



Connected Components

Basic Flow of Logic

1. Read camera input into frame buffer
2. Feed frame buffer into image processing IP
3. Read output of image processing IP
4. Use target and laser location to determine next action:
   - If laser is within threshold of target, fire (play noise)
   - If laser is not within threshold, move laser closer to target
5. Return to step 1

Our Design Process

Division of Labour

Embedded Systems

Roberto

- Audio and video IP integration
- Block design
- Integrated software (UART, (V)DMAs, etc)
- Driver software for custom IP

Patrick

- SD card subsystem (low-level SPI, FAT32)
- Sound Board, loading sound files
- Software Integration (Version Control, UART)
- Motor control (manual/automatic modes)

Hardware Design

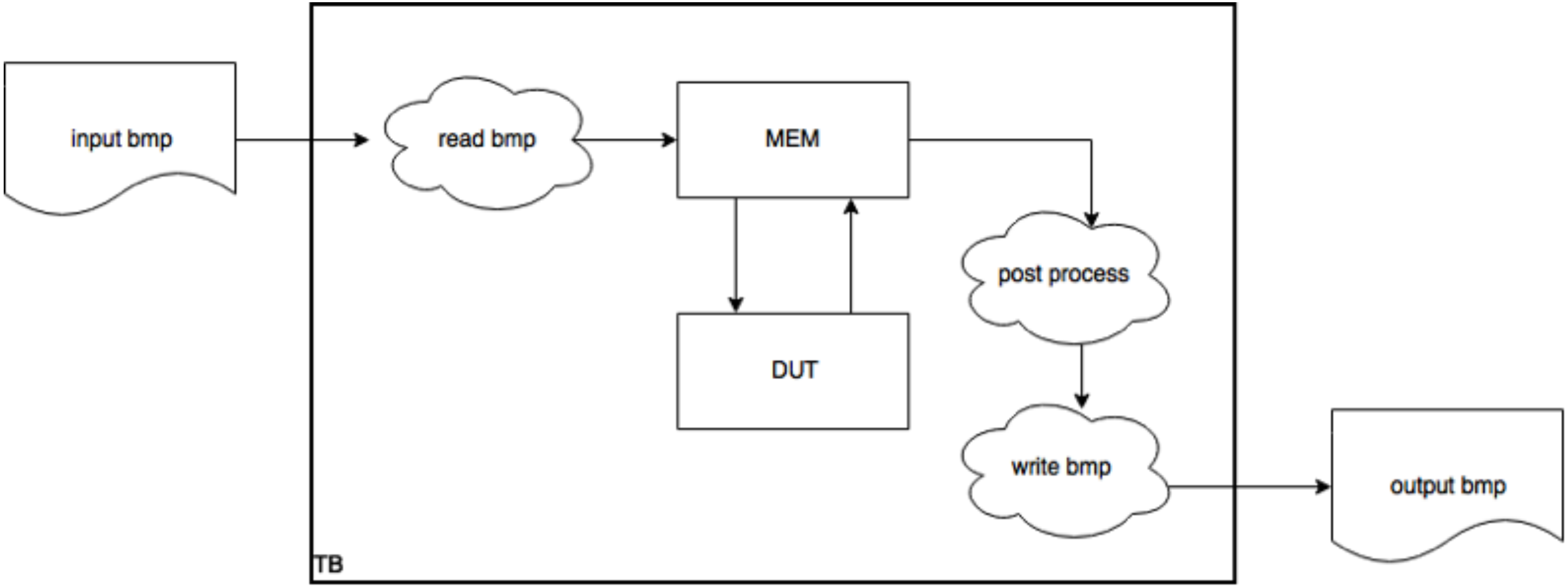
Emily

- Research into computer vision
- Software prototype
- Testbench
- Hardware implementation

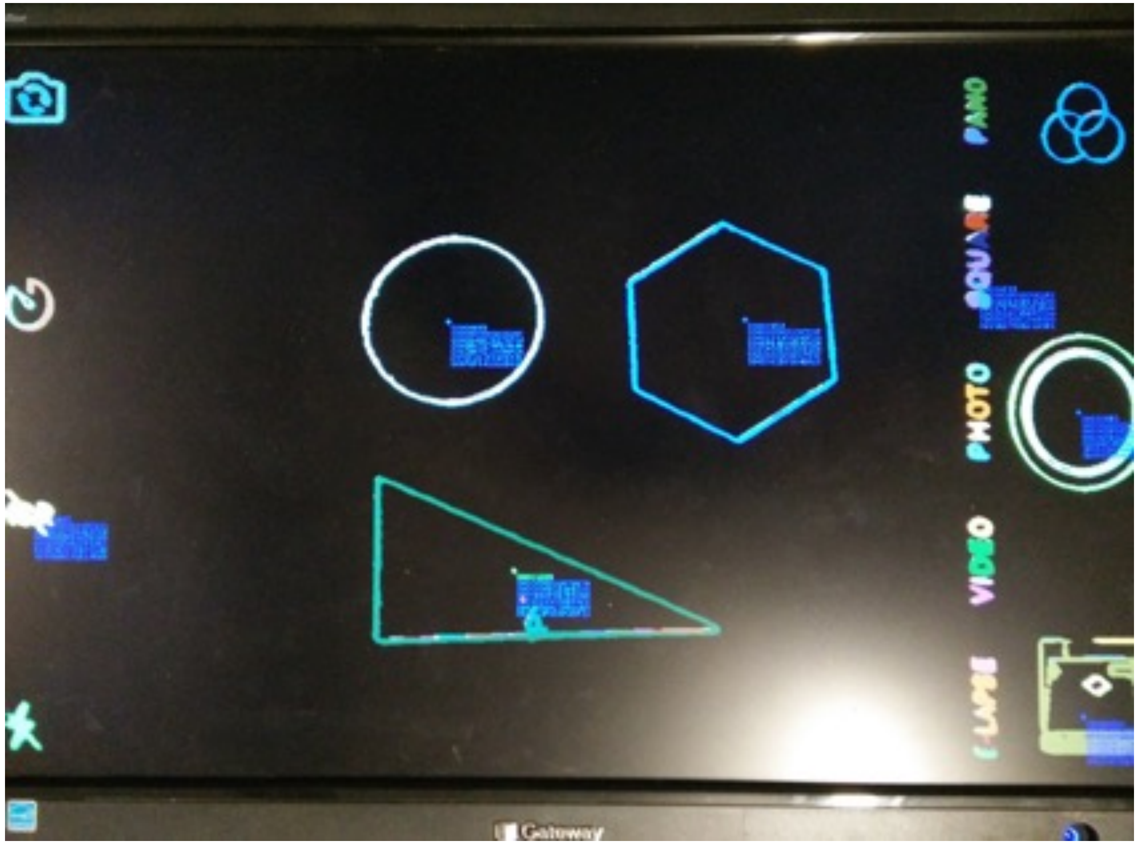
Michael

- Physical turret system and circuitry
- Servo PWM and laser driver IP
- Image processing IP shell
- Laser tracking

Testbench Setup



Hardware Testing



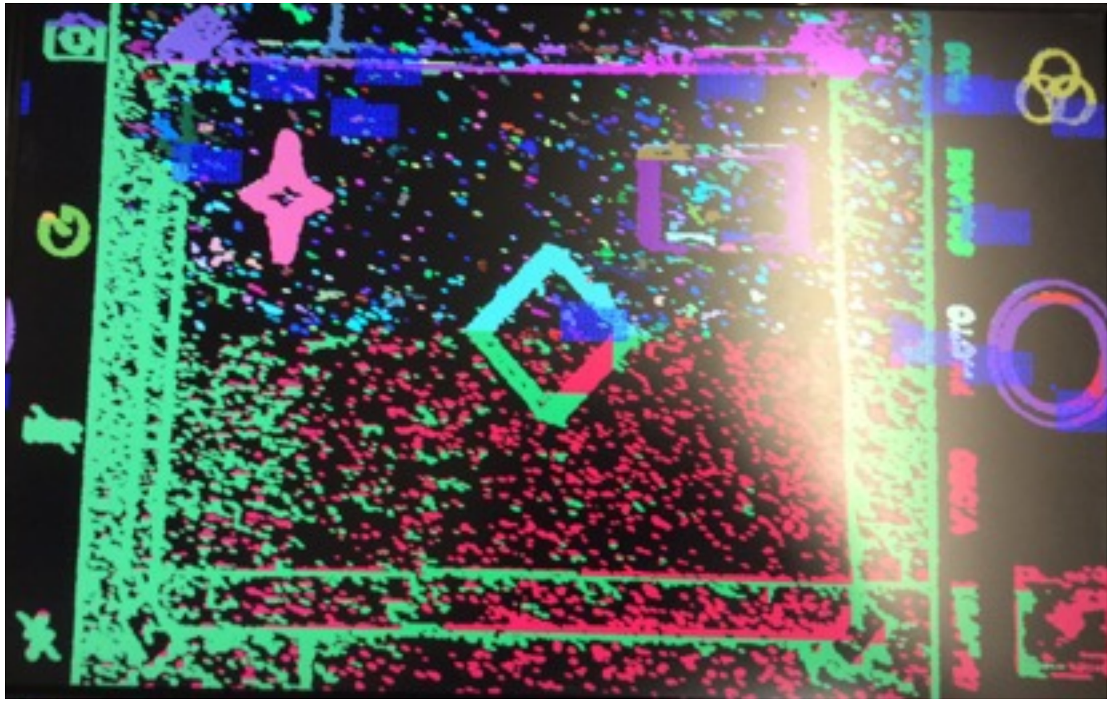
Source Control and Collaboration

- Version controlled:
  - Block diagram (as tcl)
  - IP Verilog sources
  - Software
  - Bitstream
- Work flow:
  - Scripts for creating and compiling project
- Benefits:
  - Easy to work independently
  - Easy to revert changes

Obstacles and Challenges

Video Processing IP

- Noise rejection
- Thresholds
- Environmental dependence
  - lighting
- Tradeoff:
  - laser detection vs. object detection



Embedded

- Proper configuration of VDMA IP to communicate with image processing
  - Proper timing / control signals
  - Handling bus contention with other (V)DMAs
- Could not use native SD interface
  - used slower, obscure SPI protocol
  - Support for SPI interface very poor
- Difficult to debug SD card internals
  - Simulation of SD card impossible
  - SD card is a “black box”

What We Learned

- Design should account for the variability of real environments
  - e.g. lighting, colour
- Better anticipate “bottlenecks” in the project schedule
  - HDMI
  - Held up frequently by missing hardware features
- Test out performance of peripherals early in the project
  - e.g. issues with webcam

Reference Materials

- Open-source libraries for high-level FAT32 operations
- Digilent sample projects for:
  - Video input/output
  - Audio

Thank You