Vision Integrated Robotic Turret (VIRT)

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TEXAS A&M UNIVERSITY
ROBOTICS TEAM & LEADERSHIP EXPERIENCE

Project Goal

This project aims to build a sentry robot with a Computer Vision (CV) system based on a field programmable gate array. FPGAs can support lower latency CV systems than microprocessors due to their parallel processing capabilities. VIRT will find, track, and follow a target object of known size and color, maintaining centered position at a fixed distance.

Subsystems

Chassis

- 3 DOF kiwi drive chassis with 96mm omniwheels to translate and rotate.

Power

- 14.8V 4S2P custom battery pack made of 21700 Li-Ion cells with a 9-36V to 5V buck converter powers the robot.

Motor Controls

- STM32 NUCLEO-G431RB communicates with a Zybo Z7-10 via UART and controls 3 15A motor drivers, 3 50.9:1 12V BDC motors; and 1 MG995 servo.

Computer Vision

- PCAM 5C camera captures 320x240px @30fps RGB565 video for the Zybo Z7-10 to perform pre-processing, RGB to DVI conversion, and output to a monitor.

Engineering Analysis

Chassis

VIRT uses a Kiwi Drivebase enabling omni-directional movement for the robot. On top of the chassis is a servo mounted camera that enables tracking at various heights.

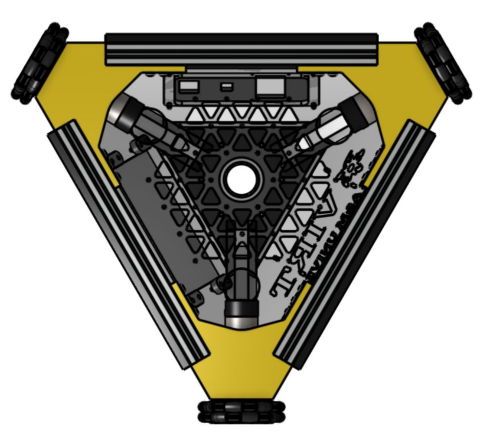

Figure 1. VIRT drivetrain

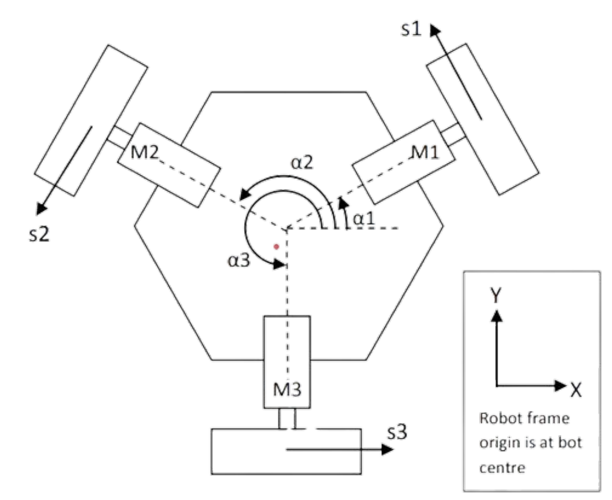

Figure 2. Wheel directions

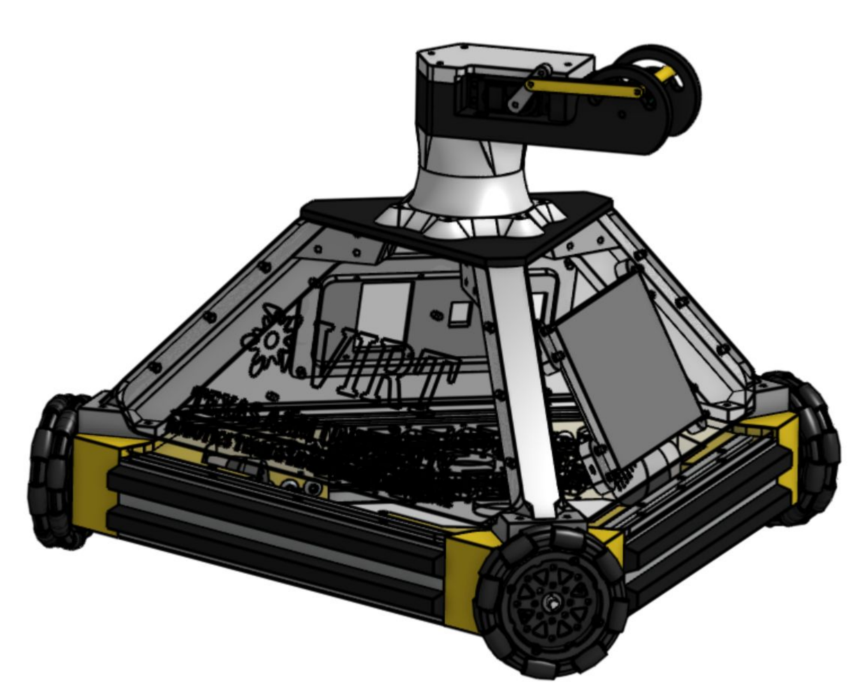

Figure 3. V3 chassis assembly

Motor Controls

The motor controls utilize vector math to determine motor speeds based on a desired movement and rotation. This enables target tracking given a difference between the centroid of the ball and the center of the camera frame.

Power System

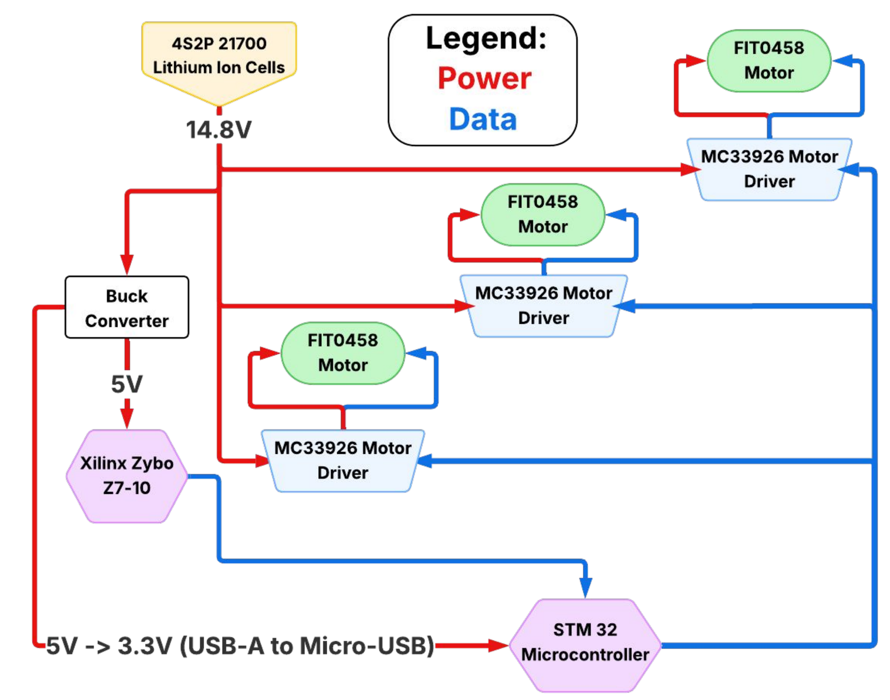

Figure 5. Motor Control System Diagram

The power system is a 4S2P Li-Ion battery pack with a fuse to limit current, a buck converter for our FPGA and STM-32, and main power shutoff.

Computer Vision System

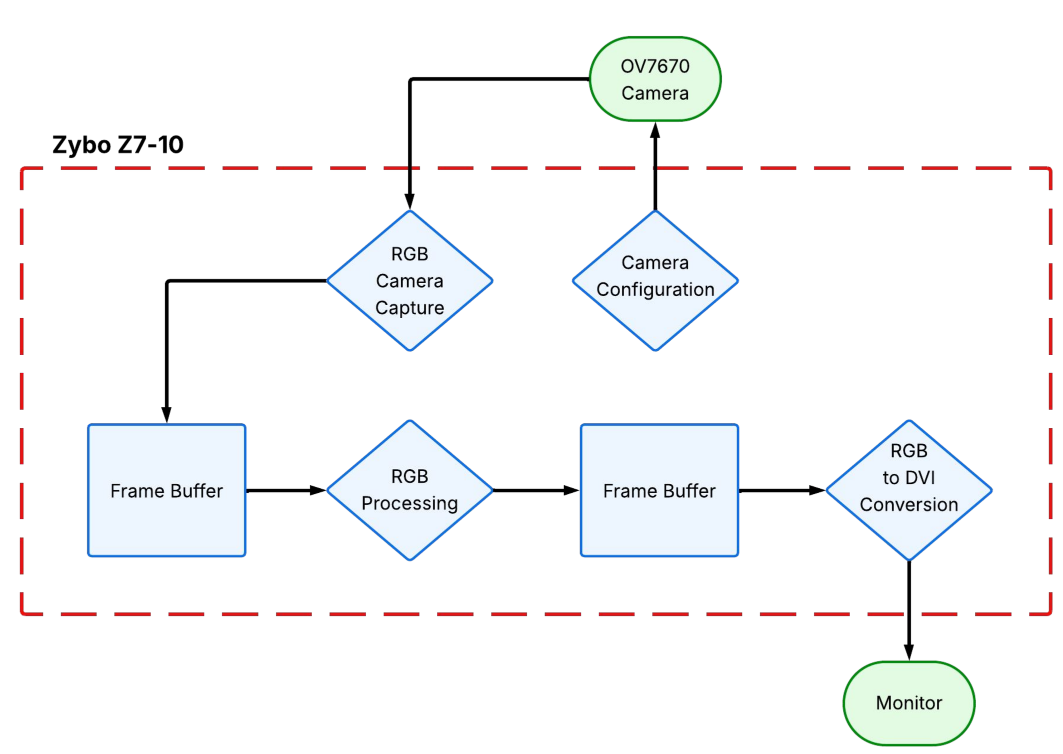

Figure 6. Computer Vision System Diagram

The CV system will find and calculate the position of an object of known color and size, based on the area of colored pixels in the image and which image segments these pixels are found in. This provides a center position relative to the center of the camera which is then sent to the microcontroller to tell the robot to move.

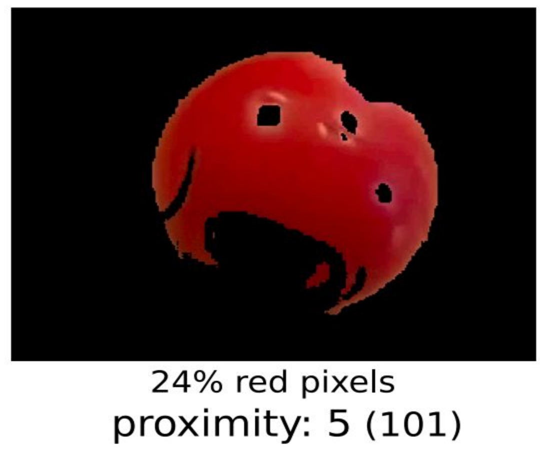

Figure 7. Pixel Proximity[1]

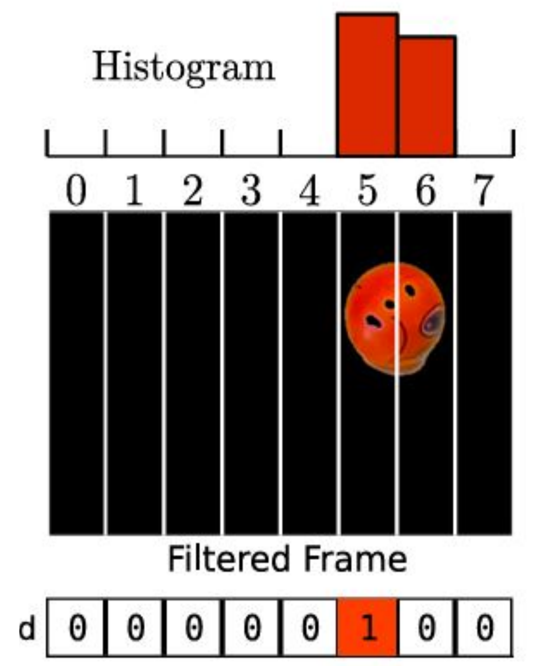

Figure 8. Representation of centroid calculation[1]

Outcomes

- Working holonomic drive base and variable angle camera mount
- Visual input to and output from the FPGA via camera and onboard monitor
- Working communication between our FPGA and microcontroller
- Preliminary object tracking pipeline running entirely on the FPGA and outputting relative position to the object

Future Plans

- Implement small scale ML models to enable face tracking at high speeds
- Full scale path planning based on FPGA face tracking

References

1 Felipe Machado, Rubén Nieto, Jesús Fernández-Conde, David Lobato, and José M. Cañas. "Vision-Based Robotics Using Open FPGAs." Microprocessors and Microsystems 103 (2023): 104974.