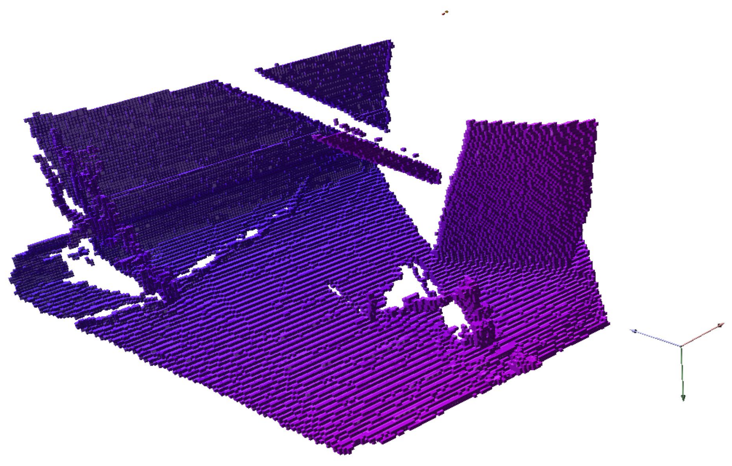
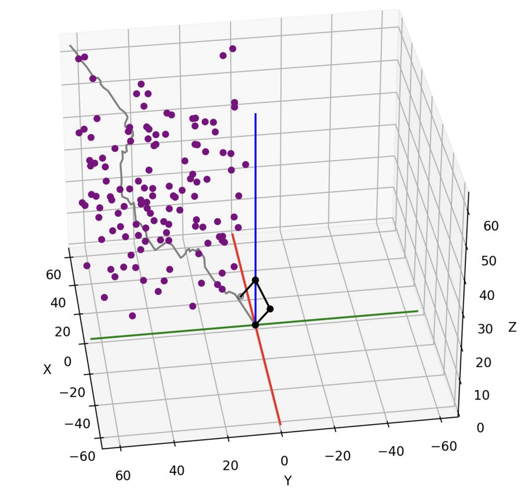
FPGA-AMP



C5: Matt Ngaw, Yufei Shi, Chris Stange
18-500 Capstone Design, Spring 2024
Electrical and Computer Engineering Department
Carnegie Mellon University



Product Pitch

- Motion Planning
  - Critical step in the robotics pipeline
  - Guides motion of the robot
  - Rapidly-exploring Random Trees (RRT) finds collision-free trajectories from a start position to a goal position
  - Run A* on the set of collision-free trajectories to find optimal route
- Problem
  - For complex, latency sensitive robots
  - RRT is too slow on CPUs, too power-inefficient on GPUs
- Solution: FPGA
  - Accelerate motion planning while also consuming less power

System Architecture

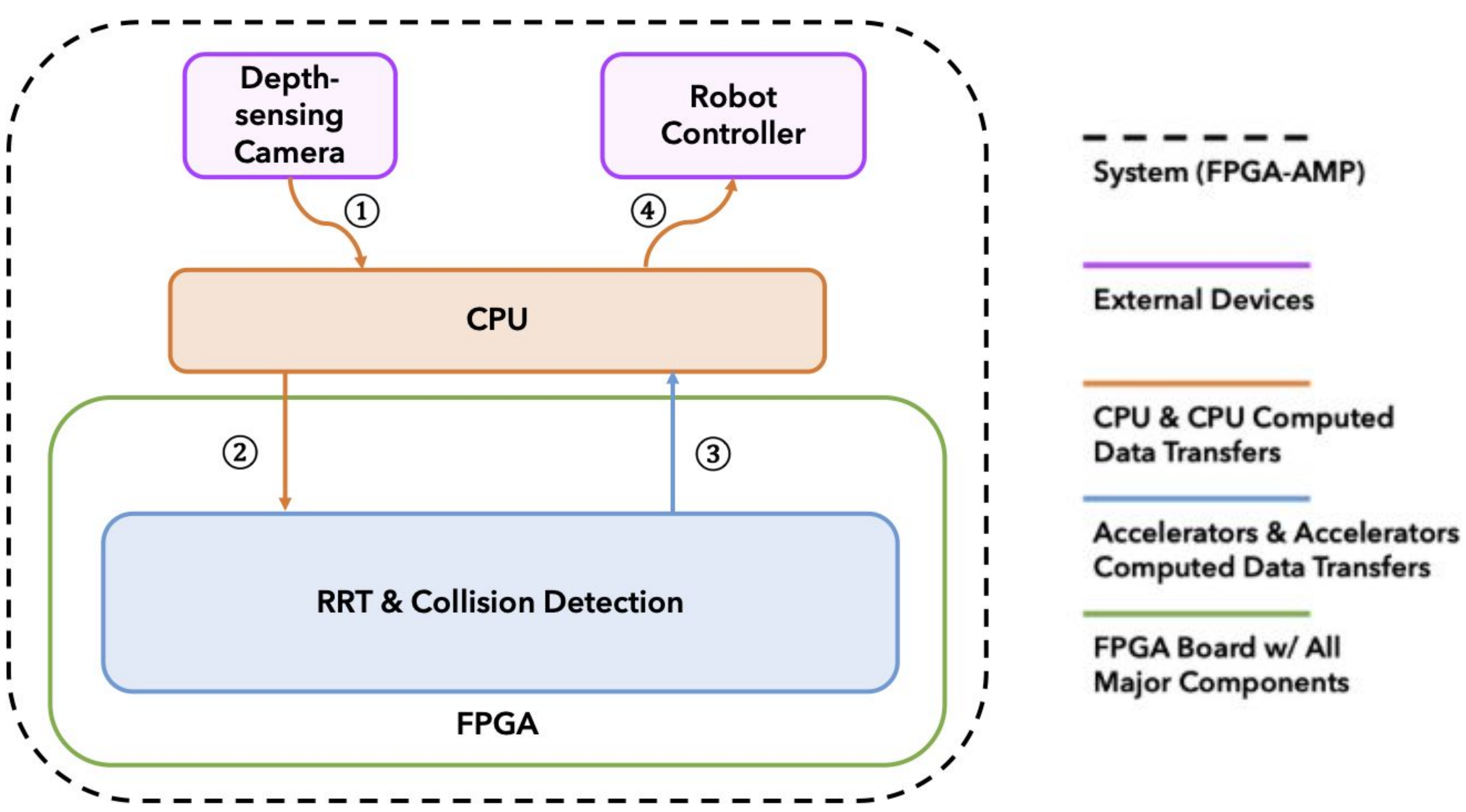


Fig 1. Overview of FPGA-AMP system

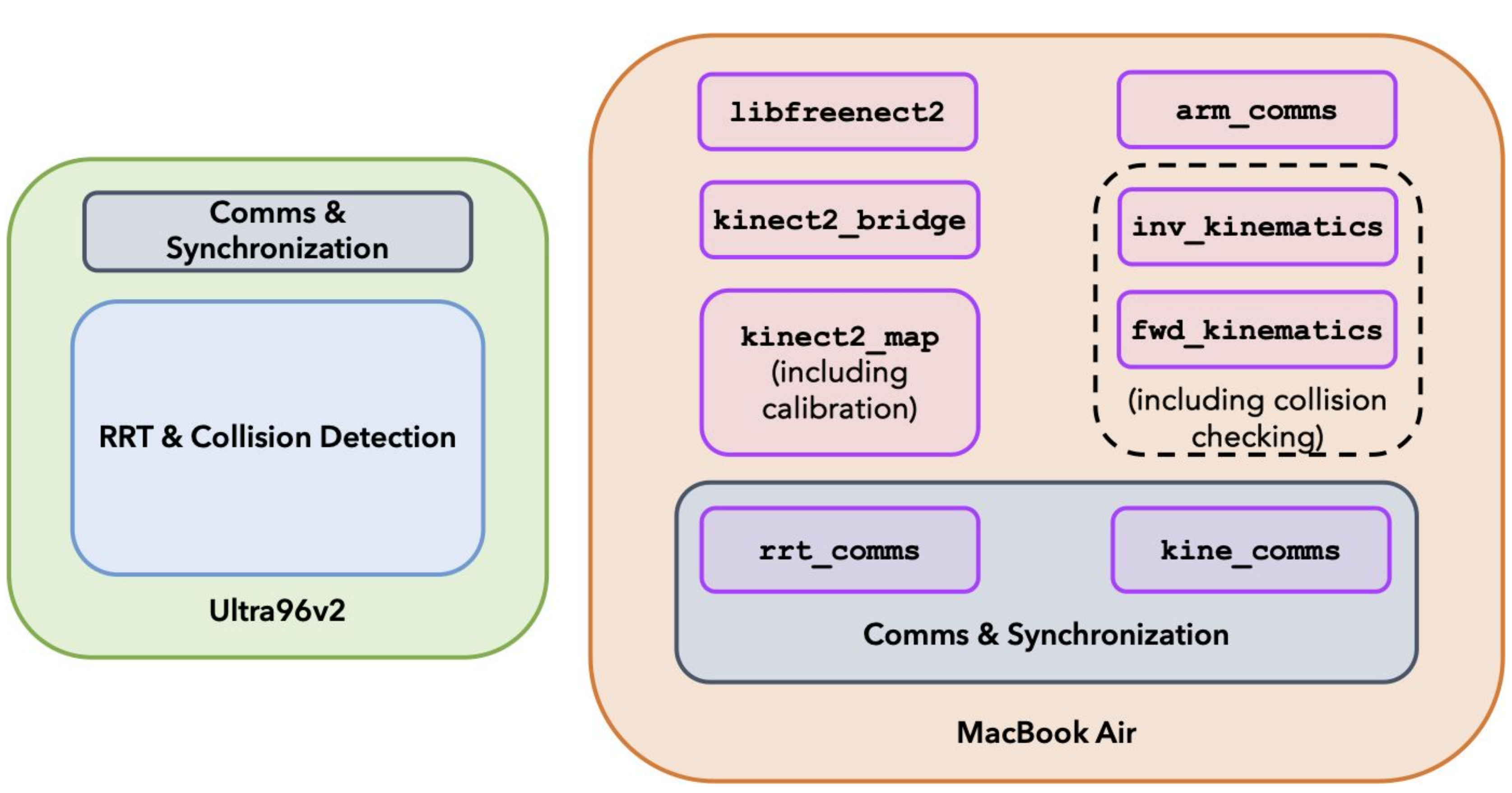


Fig 2. Components of FPGA-AMP system

Conclusions & Additional Information

https://course.ece.cmu.edu/~ece500/projects/s24-teamc5/

- The goal of our project was to accelerate motion planning and reduce its power/energy costs. We have achieved this goal.
- Developing a full robotics pipeline was done in order to effectively demonstrate the performance of our accelerator and greatly increased the scope of the project.
- Realistically, a robot deployed in a fast-moving environment would be more tightly integrated.
- Future testing of the system in dynamic environments would further highlight our accelerators capabilities.

System Description

- End-to-end system demonstrates our accelerator on robotic arm
- The full FPGA-AMP includes:
  - Perception: calibration, unwanted object pruning, and 3D mapping
  - Motion planning: software and hardware implementations of RRT
  - Kinematics: our own forward and inverse kinematics library
  - Arm control: collision checking and obstacle avoidance
  - Communications: networked data transfer between FPGA and laptop

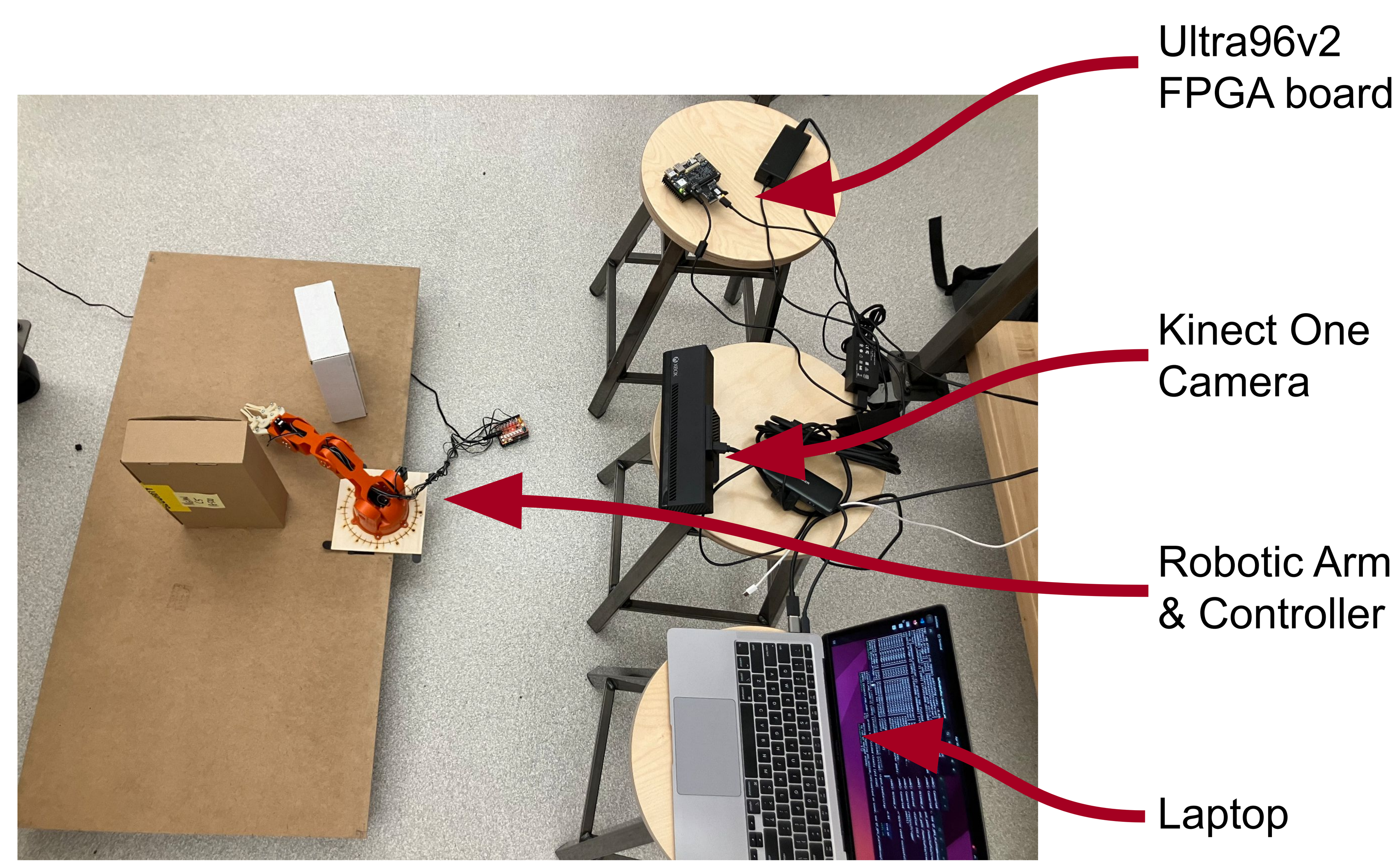


Fig 3. FPGA-AMP system setup with a test scene

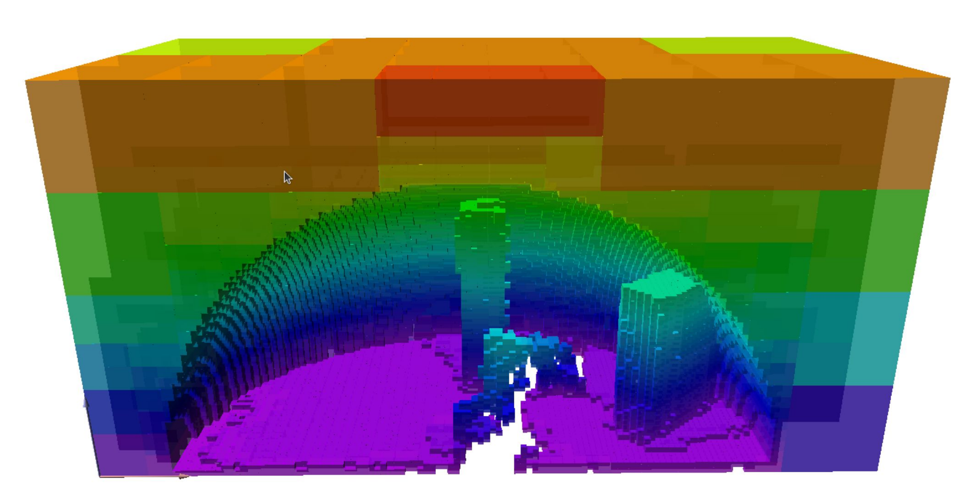


Fig 4. The 3D mapped test scene. The background and unwanted objects are removed. This scene is turned into flattened dense occupancy tensor representation and used by RRT and kinematics nodes.

System Evaluation

System Component	Current Status	Evaluation
Perception	Evaluated	> 95% accurate
Kinematics/Dynamics	Final calibration	-
Motion planning accuracy	Evaluated	> 95% accurate
Motion planning speedup	Evaluated	> 10x speedup
Motion planning efficiency	Evaluated	> 10x more power eff.

Table 1. Summary of system evaluation status (as of Apr 30)

- Benchmarked SW and HW RRT by measuring time elapsed during RRT computation
- Calculated speedup as S = (T_SW) / (T_HW)

Electrical & Computer ENGINEERING
Carnegie Mellon