Zhihao Ruan

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Work Experience

- **TuSimple, Inc.** — San Diego, CA
  Planning Research Engineer — *June 2022 – Present*
  - Developed motion planning software & algorithms for autonomous trucks.
- **TuSimple, Inc.** — Philadelphia, PA (Remote)
  Planning & Prediction Research Engineer Internship — *May 2021 – Aug 2021*
  - Developed motion planning software & algorithms for autonomous trucks.

Research Experience

- **F1/10 Autonomous Racing Group, Real-Time & Embedded Systems Lab (mLab)** — Philadelphia, PA
  CAD2CAV: Computer Aided Design for Cooperative Autonomous Vehicles.Link. — *Feb 2021 – Present*
  - Wrote graph-based multi-agent path planner in ROS (Robotics Operating System) & C++ with **Ant Colony Optimization solver for Capacitated Vehicle Routing Problem**, **Spectral Clustering**, and k**-Way Graph Partitioning**.
  - Implemented **FMT*** for real-time obstacle avoidance and **Pure Pursuit** as the controller for F1/10 autonomous racing vehicles.
  - Developed data import utility library in ROS C++ from Autodesk Revit 3D building model to ROS occupancy map.
- **Interactive Sensing and Computing (ISC) Lab** — Ann Arbor, MI
  Research Assistant of Prof. Alanson Sample, Synthetic Health Sensor — *Jan 2019 – Dec 2019*
  - Built an embedded system in **C & MATLAB** with **STM32** microprocessor and Panasonic's GridEye® 8×8 IR sensor through **I²C & UART** that can collect, detect and visualize heat distribution in the room.
  - Developed an API in C based on the **standard peripheral library (SPL)** for Panasonic's GridEye® 8×8 IR sensor for **STM32** microprocessor.
  - Implemented **Direct Digital Synthesis (DDS) in C** of a frequency-sweep ultrasonic sine wave from 39kHz to 41kHz with STM32 microprocessor and ultrasonic transducers.
  - Designed two different ultrasound distance measurement algorithms in **Python** including **FMCW (Frequency-Modulated Continuous Wave) algorithm** and **phase-based ranging algorithm** with STM32 microprocessor.

Education

University of Pennsylvania — Philadelphia, PA
- *Master of Science in Engineering in Robotics,* ***GPA: 3.9/4.0*** — *Sept 2020 – May 2022*
  General Robotics, Automation, Sensing & Perception (GRASP) Laboratory
  - **Selected Coursework:** GPU Programming & Rendering, Distributed & Multi-agent Robotics, Graph Neural Networks, Modern Convex Optimization, Reinforcement Learning, Deep Learning for Computer Vision

University of Michigan — Ann Arbor, MI
- *Bachelor of Science in Computer Science Engineering,* ***GPA: 3.9/4.0*** — *Sept 2018 – May 2020*
  College of Engineering
  - **Selected Coursework:** Embedded Systems Design (grader), Machine Learning (grader), Computer Vision, Autonomous Robotics, GPU Programming & Architecture, Operating Systems

Shanghai Jiao Tong University — Shanghai, China
- *Bachelor of Science in Electrical and Computer Engineering,* ***GPA: 3.6/4.0*** — *Sept 2016 – Aug 2020*
  University of Michigan-Shanghai Jiao Tong University Joint Institute (UM-SJTU Joint Institute)
  - **Selected Coursework:** Electromagnetics, Signals and Systems, Analog Circuits, Semiconductor Devices

Scholarship and Honors

James B. Angell Scholar — *Mar 2020*
University of Michigan Honors — *Dec 2018, May 2019, Dec 2019*
University of Michigan "Dean's List" — *Dec 2018, Apr 2019, Dec 2019*
SJTU Undergraduate Excellent Scholarship — *June 2017, June 2018*
UM-SJTU Joint Institute "Dean's List" — *June 2017, Dec 2017, June 2018*
"Honorable Mention" of 2017 Interdisciplinary Contest in Modeling — *Apr 2017*

Social Work Experience

- **Student's Union, UM-SJTU Joint Institute of Shanghai Jiao Tong University** — Shanghai, China
  Deputy Director of Media Department & Lead of Photography Team — *Aug 2017 – Jul 2018*
  - Provided photos & wrote news for all student's events on institute's official social media platforms.
  - Arranged team building events for Student's Union.
- **Center for Learning & Teaching, UM-SJTU Joint Institute of Shanghai Jiao Tong University** — Shanghai, China
  Teaching Assistant for VY 200: Academic Writing II — *Mar 2018 – May 2018*
  - Assisted professor on homework & quizzes grading, in-class activities organization.
  - Held office hours & provided instructions for writing academic essays.

Project Experience

- **Implementation of Dynamic Vehicle Routing (DVR) Algorithms** — Philadelphia, PA
  MEAM 624: Distributed Robotics — *Apr 2022 – May 2022*
  - Implemented m**-SQM, UTSP,** m**-Divide and Conquer**, and **No-Communication** dynamic vehicle routing (DVR) policies in Python and a self-designed distributed robotic simulation framework.
  - Realized the **geometric optimization** method over power diagram for **distributed partitioning** based on the paper "Distributed algorithms for environment partitioning in mobile robotic networks" in Python.
- **DevDAgger: Data-Efficient Visual Imitation Learning through CNN and Gaussian Process** — Philadelphia, PA
  CIS 700: Probabilistic Methods in Machine Learning — *Nov 2021 – Dec 2021*
  - Propose a novel data-efficient vision-based DAgger architecture with CNN and Gaussian Process.
  - Implemented the model in Pytorch & GPytorch and reached reasonable efficiency improvements compared to vanilla DAgger.
- **Volume ReSTIR Implementation in Vulkan** — Philadelphia, PA
  CIS 565: GPU Programming & Architecture — *Nov 2021 – Dec 2021*
  - Built an **RTX hardware-accelerated Vulkan ray tracer** from scratch in C++.
  - Implemented volumetric ReSTIR rendering based on paper "Fast Volume Rendering with Spatiotemporal Reservoir Resampling" using **Vulkan compute shader** and **ray tracing shaders**.
- **Physically-Based Ray Tracing Implementation in CUDA** — Philadelphia, PA
  CIS 565: GPU Programming & Architecture — *Sept 2021 – Oct 2021*
  - Built a **Physically-Based Ray Tracing (PBRT)** renderer in standard CUDA kernel with OpenGL backend and C++.
  - Implemented **À-Trous denoising** algorithm in CUDA over the ray traced image from the PBRT renderer.
- **Minimum-Snap Trajectory Generation and Control for Quadrotors** — Philadelphia, PA
  ESE 650: Learning in Robotics, Univ. of Pennsylvania — *April 2021 – May 2021*
  - Planned quadrotor trajectory in densely cluttered environments with **A*/Dijkstra's Algorithm** .
  - Formulated minimum-snap trajectory smoothing algorithm into a **Quadratic Programming (QP) problem** with CVXPY.
  - Designed **Constrained Gradient Descent solver** to optimize time duration for each min-snap trajectory segment.
  - Analyzed quadrotor dynamics and developed **Non-linear Geometric Controller** for quadrotors.
- **Mini Minecraft in C++** — Philadelphia, PA
  CIS 560: Interactive Computer Graphics, Univ. of Pennsylvania — *Nov 2020 – Dec 2020*
  - Achieved mesh rendering with **interleaved Vertex Buffer Object (VBO)** data in Qt and OpenGL and applied **CPU parallel optimization**.
  - Created **procedural weather** effect in GLSL shader program, **L-system** river generation, **procedural terrain** generation with **Perlin Noise** and terrain smoothing with **Fractal Brownian Motion (FBM)**.
  - Implemented mesh collision checking with **ray tracing** and **3D grid marching**.
  - Created and implemented **animated texturing** for "grass," "dirt," "stone," "ice," "water," "lava," etc.
  - Developed **redstone texturing & redstone circuit logic**; supports "redstone wire," "power lever," "redstone torch".
- **Deep Neural Network Implementation for Machine Perception** — Philadelphia, PA
  CIS 680: Advanced Topics in Machine Perception, Univ. of Pennsylvania — *Sept 2020 – Dec 2020*
  - Implemented **YOLO v1** for object detection in **PyTorch**, featuring anchor-based detection & **Non-Max Suppression (NMS)**.
  - Implemented **SOLO** for instance segmentation, using **ResNet50 FPN** as backbone and **MatrixNMS**.
  - Implemented **Regional Proposal Network (RPN)** and **FasterRCNN** object detection head using ResNet50 FPN as backbone, featuring **ROI Pooling**, reaching an **mAP of 0.581**.

- Implemented multiple GAN architectures including **Variational Auto-Encoders (VAE)**, **DC-GAN**, **CycleGAN**, **BicycleGAN**. Achieved **Fréchet Inception Distance (FID)** score of 70.87 on CycleGAN and 76.82 on BicycleGAN.

- **Computer Graphics Development with OpenGL** — Philadelphia, PA
  CIS 560: Interactive Computer Graphics, Univ. of Pennsylvania — *Sept 2020 – Nov 2020*
  - Implemented **3D mesh rasterization** with provided mesh file in **Qt 5.15** and **OpenGL**, integrated with **scene graphs**, with polar spherical camera model, perspective-correct **barycentric interpolation**, texture mapping, Lambertian reflection, and custom-scale **anti-aliasing**.
  - Designed various shaders in **GLSL** including **Blinn-Phong reflection** shader, **Worley noise** shader, Gaussian blur shader, and **Matcap** shader.
  - Built an deformable/editable mesh with **Half-edge mesh structure**, featuring a Maya-like application interface with Qt and **Catmull-Clark surface subdivision**.

- **Real-Time On-Device Flow Statistics Detection and Prediction** — Shanghai, China
  Undergraduate Major Design Experience, UM-SJTU Joint Institute — *June 2020 – Aug 2020*
  - Built a system in **Python** which detects human traffic flow, automatically analyzes & detects entrances on **Raspberry Pi 4B**, stores data on a server, visualizes analyzed data on a self-designed front-end website **in real time** ($\sim$ 15 FPS with Google Coral Edge TPU USB accelerator).
  - Achieved **20 FPS and 90% accuracy** object tracking & people counting with **self-designed Kalman filter tracker**, automatic entrance detection with density-based clustering algorithm — **DBSCAN** in Python.

- **Linux Infrastructure Implementation on x86 PCs** — Ann Arbor, MI
  EECS 482: Introduction to Operating Systems, Univ. of Michigan — *Jan 2020 – Apr 2020*
  - Implemented mutex, conditional variables & thread class using context switching API in **Linux kernel library** with multiprocessor support provided using **interrupt handling** and **CPU guard** in C++.
  - Built Unix pager with swap-backed & file-backed pages with **page fault handing** and **process switching & forking** support in C++.
  - Emulated Unix-style file system using inode and directory entry structures with client request handling using **Berkeley sockets** and safe concurrency using **C++ Boost library**.

- **MXNet Optimization with GPU** — Ann Arbor, MI
  EECS 498: GPU Programming & Architecture, Univ. of Michigan — *Nov 2019 – Dec 2019*
  - Implemented GPU parallelization of forward kernel of MXNet incubator 1.3.x with **tiled matrix multiplication** and **GPU shared memory**; boosted inference speed **from 30s to $<$ 3s** on fashion-mnist dataset and Nvidia TITAN Xp graphics card.

- **DOAPP: Dynamic Object Avoidance and Path Planning** — Ann Arbor, MI
  Undergraduate Major Design Experience, Univ. of Michigan — *Oct 2019 – Dec 2019*
  - Implemented a **GPU-accelerated motion planning algorithm** originally proposed by Chonhyon Park, et al. in **ROS C++ & CUDA** with Nvidia GPU parallel programming & optimization that could perform **real-time obstacle avoidance**.
  - Built a controller and trajectory follower in **ROS C++** for Dynamixel motors on robot arm from scratch and achieved **30 Hz signal transmission**.

- **Robotics Algorithm Development in LCM (*Lightweight Communications and Marshalling*)** — Ann Arbor, MI
  EECS 467: Autonomous Robotics, Univ. of Michigan — *Sept 2019 – Oct 2019*
  - Implemented a SLAM algorithm in C++ with **occupancy grid mapping, particle filter localization, A* path planning.** Entire system run on a mobile robot with Raspberry Pi 3 and LiDAR.
  - Implemented robot manipulation algorithms in Python including **Forward Kinematics, Inverse Kinematics (based on Geometry).** Entire system run on a mobile robot with robot arm that could localize & pick up a block using AprilTag automatically.

- **Cost-Function Prediction Market Simulation with Bayesian Traders** — Ann Arbor, MI
  ML Research Paper Reading Group of Prof. Sindhu Kutty, University of Michigan — *May 2019 – Aug 2019*
  - Simulated **cost-function based prediction market** mechanism **in Python**, with its performance evaluated and compared with traditional machine learning algorithms.
  - Reconstructed exponential-family prediction markets in different probability distributions **mathematically**.

- **Interactive Game: *Step on White Tiles*** — Ann Arbor, MI
  EECS 373: Introduction to Embedded Systems Design, Univ. of Michigan — *Mar 2019 – Apr 2019*
  - Visualized black & white tiles flow by driving a projector with **FPGA** by programming **VGA protocols in Verilog**.
  - Decoded signals from Nintendo controller in Verilog.
  - Built **a complete menu selection user interface in C** on an LCD display with SmartFusion® microprocessor and Nintendo controller.
  - Achieved stepping detection on projected tiles through **SPI protocol in C** with Pixy® camera.
  - Enabled sound effects using SmartFusion® microprocessor, Adafruit® Audio Sound Board and Dell® stereos in Verilog.

Skills

Programming Languages: C/C++, Python, MATLAB, Verilog.
Development Tools: CVXPY, STM32CubeMX, OpenCV, PyTorch, Scikit-Learn, LCM (Lightweight Communications and Marshalling), ROS (Robotics Operating System), CUDA