

# 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* Feb 2021 – May 2022
  - Built a 3D building model rendering pipeline in **Unreal Engine 4** for 2D AutoCAD floor plans.
  - 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.
  - Applied **Cartographer SLAM** and **on-board Tiny-YOLO v4 object detection** on F1/10 autonomous racing vehicles.
- 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 **I<sup>2</sup>C & UART** that can collect, detect and visualize heat distribution in the room.
  - Constructed **a complete C API** for Panasonic's GridEye® 8 × 8 IR sensor for **STM32** microprocessor from scratch.
  - 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* 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

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- **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

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- **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 **Å-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** (~ 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** 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 Kuty, 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

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**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