Ocean drones mesh network

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Figure 1: S1 Sailboat dragging electronic box, G1 motorboat test platform, G2 motorboat test platform (left to right)

Problem

Realtime maritime data is valuable for ship route planning and weather prediction, yet we have no way to collect real-time (update frequency < 20 min) maritime data in a large scope due to the limitation of power efficiency and satellite communication.

Proposed solution

In order to tackle the problem above, we proposed to design an USV unit that has the functions below:

1. Real-time collection of sensor data, such as position coordinates, air temperature, seawater temperature, inertial measurement, etc.
2. Form a mesh network with other USVs, which can send, receive and forward data with other nodes in a certain range via radio antenna.
3. After receiving the command, it can automatically cruise to the specified coordinates and maintain the position within a certain radius.
4. Energy self-sufficient, charging through solar panels and hydro generators

Working Scheme

The project is still on-going, we worked on 2 processes in parallel, and they will be integrated into one design in the future.

1. Motorboats are for testing the robustness and stability of our data collection and transmission:
   G1: two working boats in the lab, still need some stability tests on the mesh network
   G2: a swarm of motorboats (more than 10) with our own control system, and optimized hull design.

2. Sailboat is designed as the prototype of the final product, it should be self-sufficient and have enough space for mounting all the electronics from G2 in the future:

S1: based on an off-the-shelf RC sailboat, S1 is for testing the autonomous control system

S2: customized design aiming for our ultimate purpose

Technical Details

Figure 2: The controller and other electronics such as wind vane are mounted in a tote dragged by the sailboat because of space limitation. The specially designed connection mechanism between the tote and the sailboat allows the tote to maintain horizontal regardless of the gesture of the sailboat.

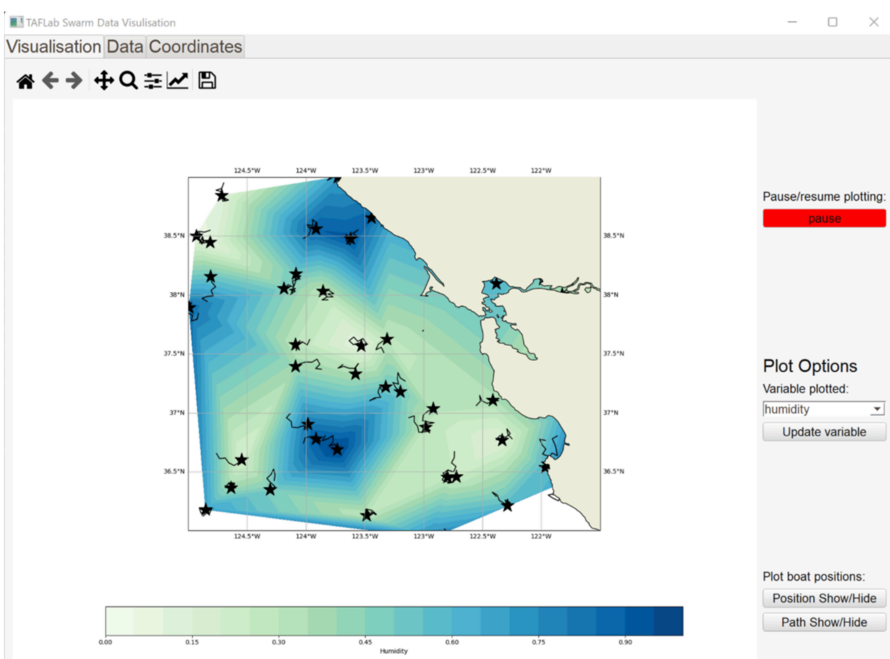

Figure 3: GUI design for control multiple boats simultaneously and plotting the heat map from real-time data collected.

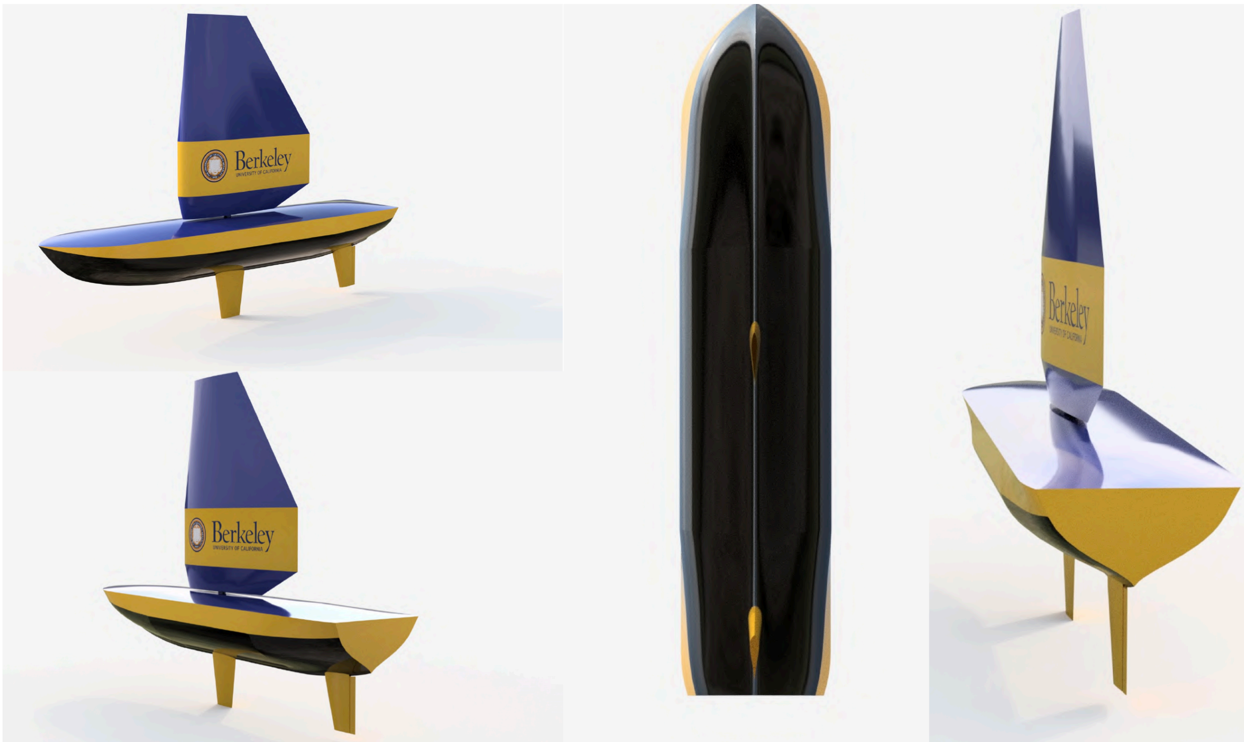

Figure 4: CAD Mockup of S2 sailboat Design, will be manufactured in the future and equipped with electronics that was already tested in S1 and G2.

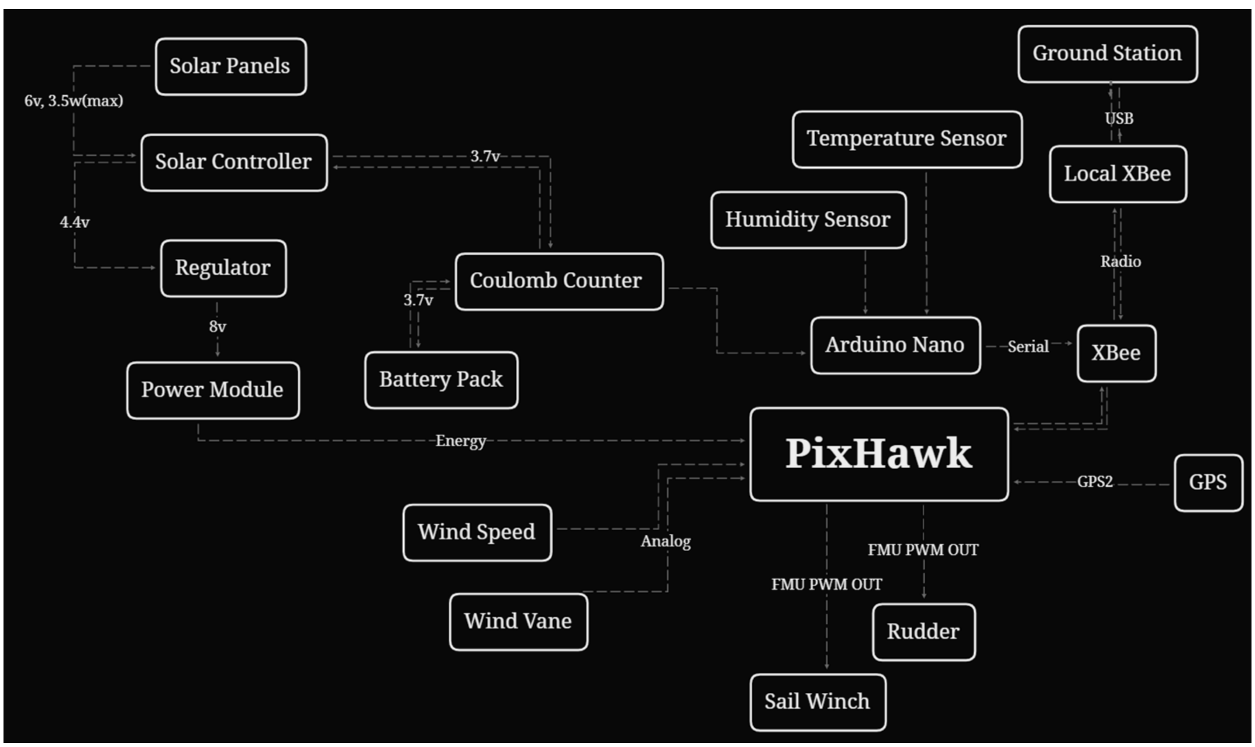

Figure 5: G1 Hardware Block Diagram, pixhawk and Arduino are replaced by beagle bone blue controller in the newest G2 boat

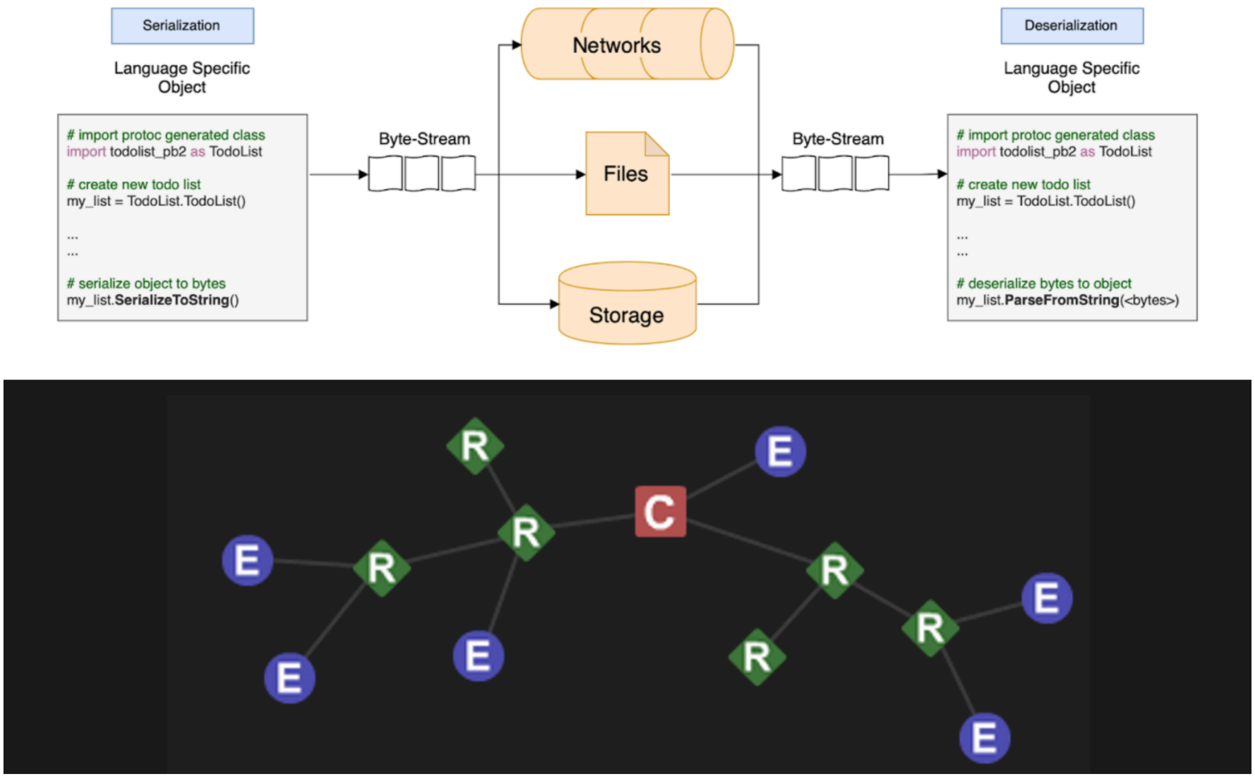

Figure 6: Google Protobuf working scheme and XBee mesh network demo. We used XBee 3 module to create a mesh network among all the boats for real-time communication, protobuf message is utilized to shrink the size of each message.

My Contribution

1. I built the first generation of electrical systems, including autopilot based on ArduRover firmware, ocean environment sensors using Arduino, and mesh network communications based on DigiMesh protocol.
2. I also designed G2, the second generation of twin-hull motorboat testing platforms using pink insulation foam, which was 60% lighter, 200% faster and 50% cheaper compared to what was previously being used.
3. As a part of my thesis, I worked with another undergrad to integrate all the controls into BeagleBoard.
4. Reduced packet size by 75% using google protobuf.

Leadership

On behalf of Prof. Alam, I took charge of the new undergraduate apprentices' selection of 2022 fall semester. As the project manager of five undergraduates and five graduates, I planned a general work scheme, divided the work with everyone's strengths in mind, organized weekly meetings and water tests, and managed group documentation on Notion.

Scenic VR

Developing An Intelligent Tutoring System (ITS) to Train Psychomotor Skills in Virtual Reality

Authors: Edward Kim, Alton Sturgis, James Hu, Yunzhong Xiao, Boxi Fu, Kyle Cui, Isaac Gonzalez, Daniel He, Zachary A. Pardos, Björn Hartmann, Sanjit A. Seshia

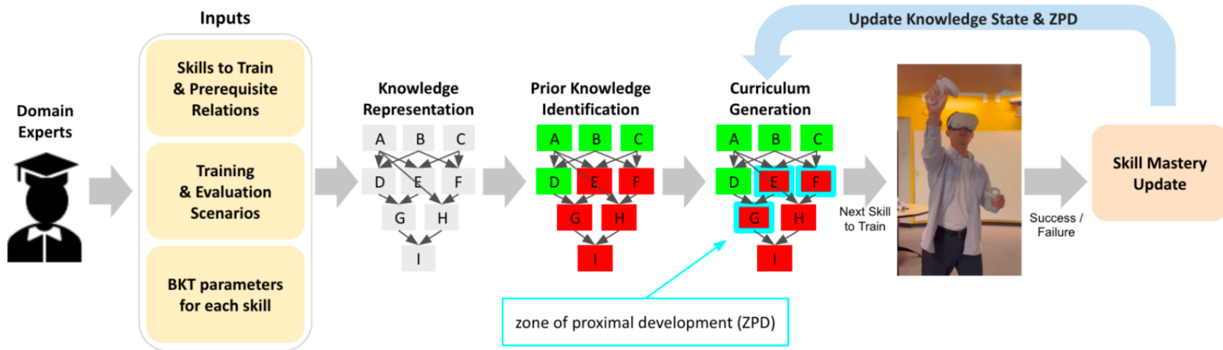

Figure 1: An overview of our proposed intelligent tutoring system architecture for training psychomotor skills in virtual reality

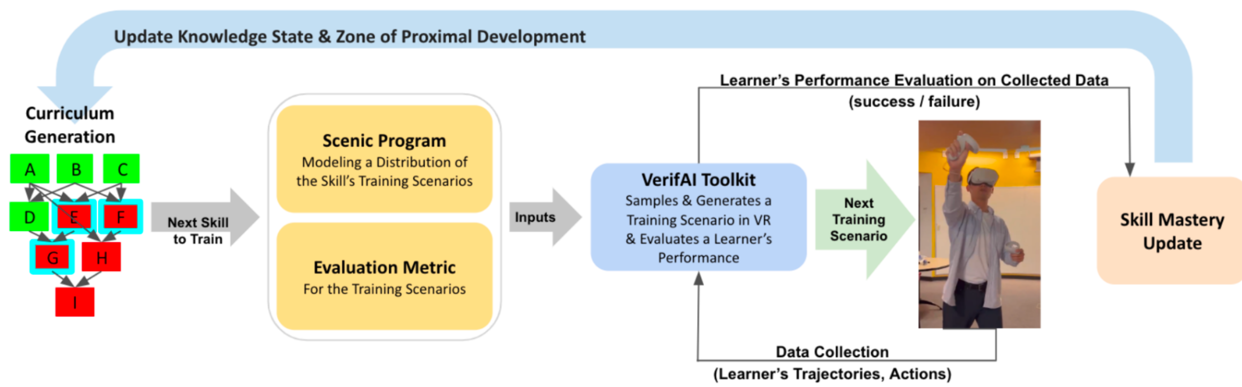

Figure 2: This figure expands the curriculum generation aspect visualized in Fig. 1. Once we select which next skill to train for, we input a SCENIC program modeling a distribution of training scenarios for the skill and its evaluation metric to VERIFAI toolkit. Then, VERIFAI samples a training scenario from the program, generates it in the learner's VR headset, and assesses the learner's performance using the given metric. This assessment is used to update the skill's BKT model.

Context

Intelligent tutoring systems (ITS) have proven successful in academic settings to personalize education to students' varying learning speeds and background knowledge especially when students have limited access to instructors. Similar issues arise when learning psychomotor skills, which consist of spatial perception, cognitive planning, and physical execution of the desired plan via coordination of multiple body joints. Therefore, ITS can potentially be helpful in this setting as well. However, ITS are traditionally designed for purely cognitive skills without any physical motor skills. Most of the literature on ITS for psychomotor skills do not elucidate why certain components of ITS architecture are relevant to these skills requiring motor skills.

Objective

We propose to design our ITS in a way that takes slip rate as a configuration parameter explicitly. Our VR application domain is a popular multiplayer frisbee game, Echo Arena. The skill characteristics for the game is dynamic, interactive, teamwork and real-time

Technical Details: 4 steps

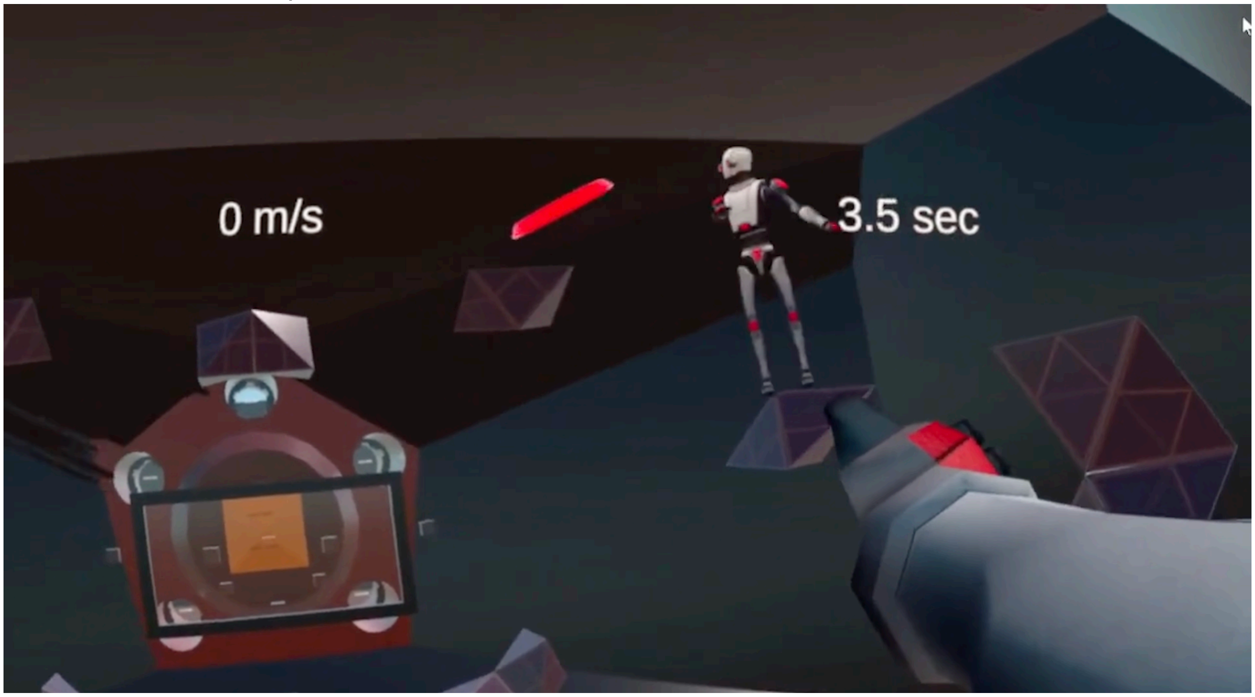

Figure 3: Modeling and Generating Training and Evaluation Scenarios in VR using Unity 3D, this screenshot shows what the trainee will see during one of the training scenarios, which is passing the disc accurately to the teammate.

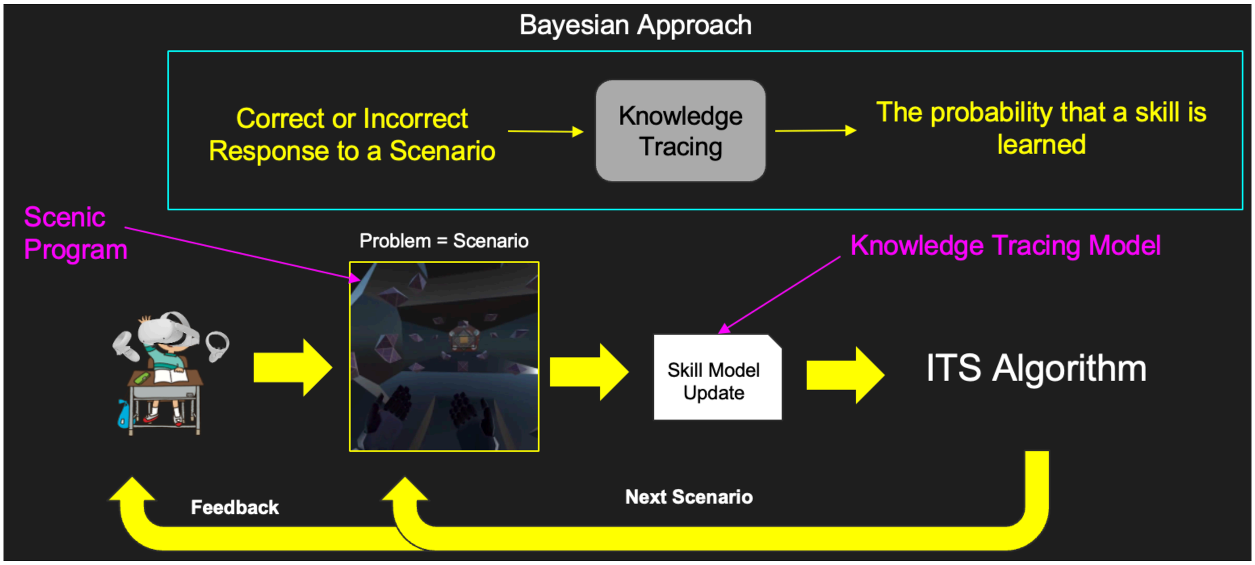

Figure 4: Bayesian Knowledge Tracing (BKT) working scheme, used for estimating student mastery of a single skill

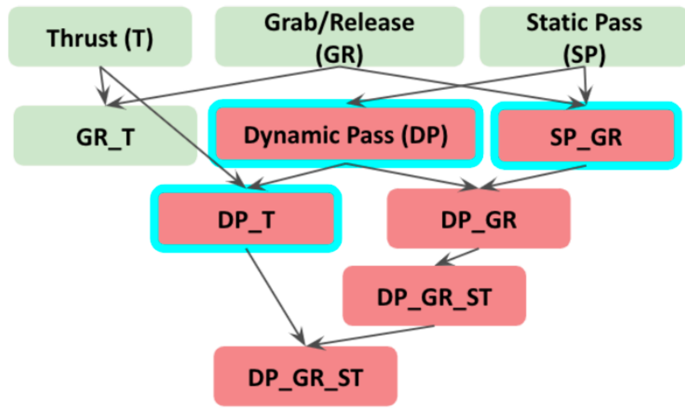

Figure 5: We represent a knowledge state as a colored, acyclic, directed, pre-order graph as visualized in this figure. Each node represents a skill. The directed edges encode prerequisite relations. The color represents mastery (green: mastered, red: not mastered). The zone of proximal development (ZPD) highlighted in light blue is a set of not mastered skills that are in proximity to mastered ones.

Outcome

To address the efficacy of our ITS, we conducted between subjects study and compared to a control condition based on self-guided learning. Our results show that our ITS had 32.3% higher learning gains than the self-guided baseline (p-value < .05) with an effect size of 0.41.

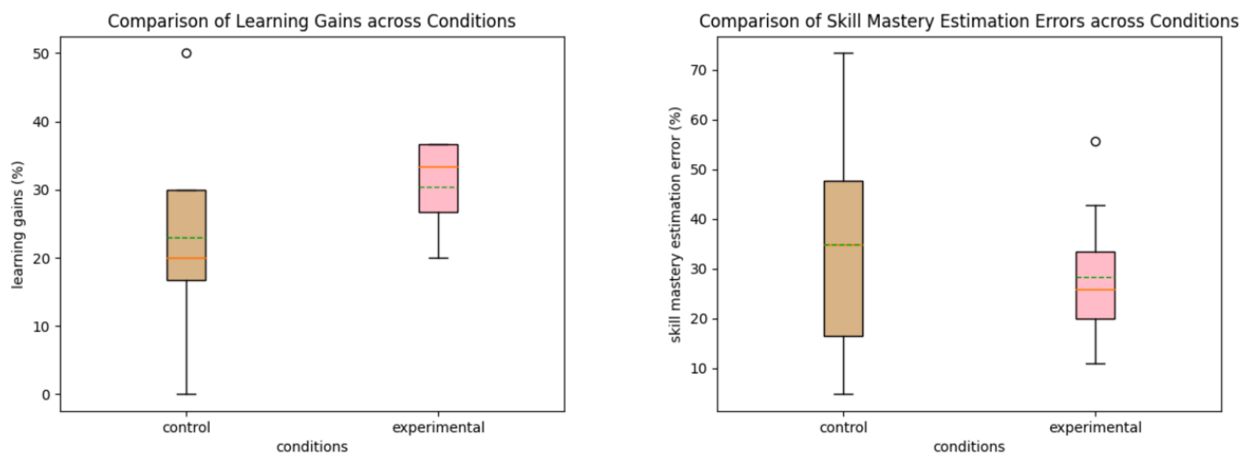

Figure 6: The left box plot shows that the experimental group had higher learning gains in comparison to the self-guided control group. The right box plot shows that the bayesian knowledge tracing models have lower error in estimating skill mastery when compared to learners' self-assessment in the control group. The green dotted line in the box plot represents the average and the orange line, the median.

My Contribution

1. To represent knowledge dependencies, I developed a Knowledge Identification algorithm based on a directed acyclic graph data structure. The algorithm recursively traversed the graph and output the next evaluation scenario with minimal steps for identifying trainees' prior knowledge.
2. In order to evaluate the trainee's skill mastery, I wrote Python scripts to monitor the trainee's physical behavior in VR and provide feedback prompts.
3. I also created a pyBKT package interface to fit the Bayesian model prior to the human experiment
4. I co-developed the VR animation on a Unity 3D engine.

Grass Hoper

A Mobile Robot Solution for Grasslands Cow Manure Pollution

Team: Yunzhong Xiao (Team Leader), Zhengxiang Zhang, Ziyu Wei, Tongge Yu, Jingyi Lai, Shu Ban

Objective

In Inner Mongolia of China, thousands of tons of manure are produced by cow husbandry each year, polluting the underground water and hardening the earth. However, with proper collection and processing, manure could have great economic value as backup energy or fertilizer. We proposed to design a mobile robot that can collect those manure on the grasslands automatically.

Technical Details

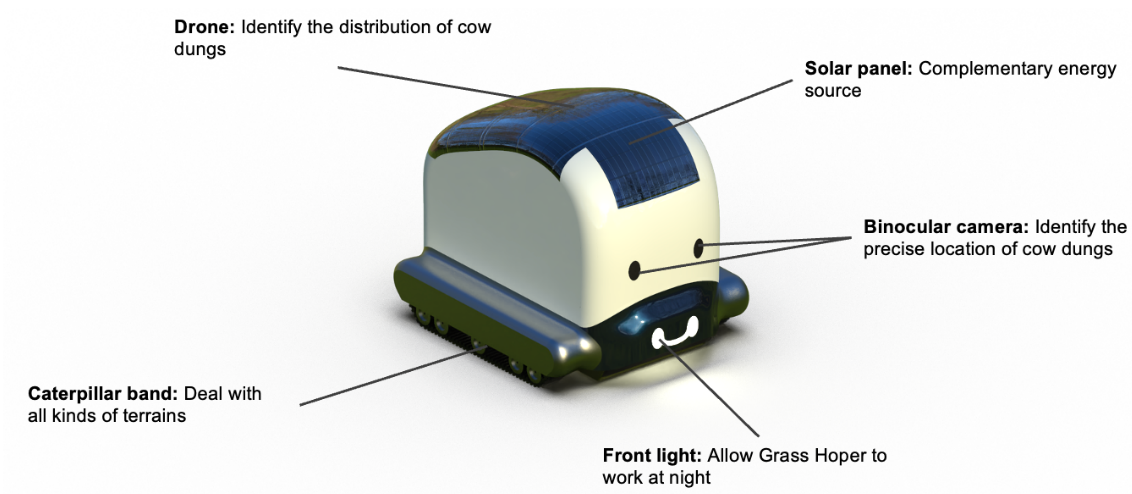

Figure 1: Outer Design

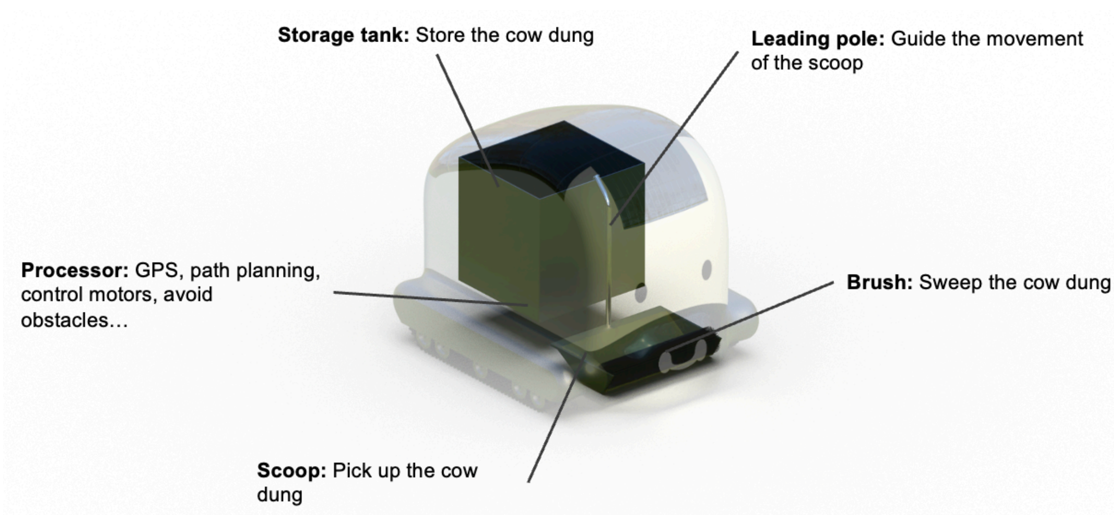

Figure 2: Inner Design

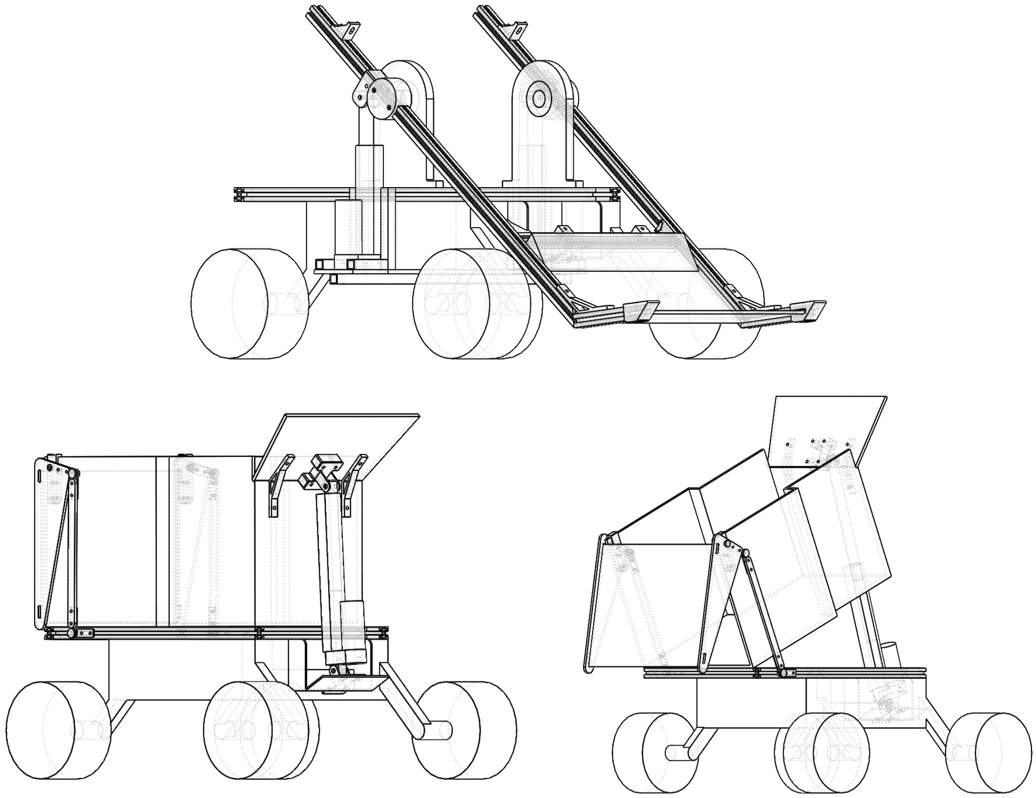

Figure 3: Mechanical Structure Design

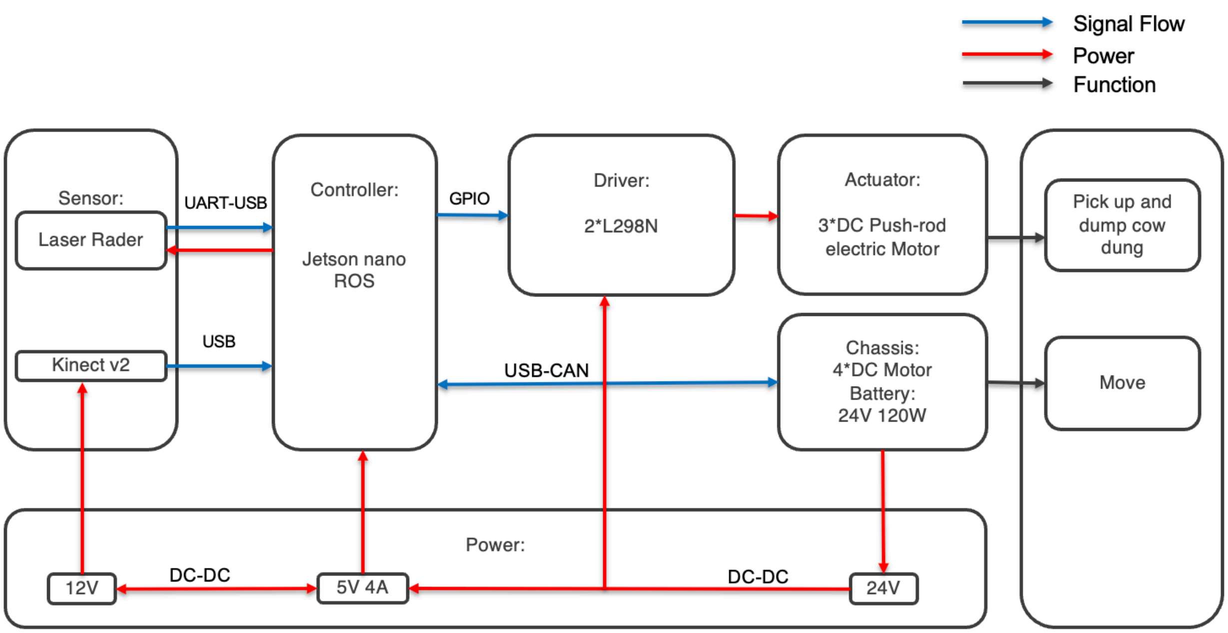

Figure 4: Hardware Block Diagram

Figure 5: Real Prototype equipped with Kinect RGBD Sensor

Outcome

Our conceptual design earned the 2nd highest score among the school and got great responses from the farmers community. The real prototype is basically functional for collecting clay material on artificial grassland.

My Contribution

1. Estimated ROI and ROT based on the overall data and potential market size.
2. I implemented object detection using RGBD camera Kinect V3 and integrated control system to Jetson Nano board with another undergraduate.
3. To keep the mechanical design team, electrical engineering team, and user investigation team on the same page, I organized weekly meetings and make sure every voice is heard.
4. I organized our presentation and designed our efficient working scheme.