National Aeronautics and Space Administration

Onboard RGB-D Perception for Lunar Cable Deployment

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ABSTRACT

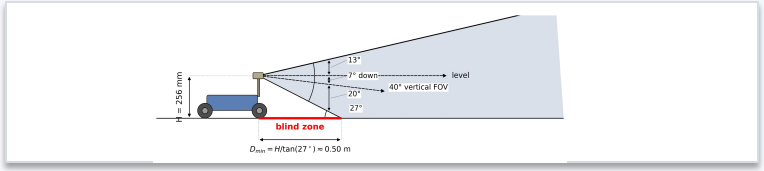
Future lunar bases may rely on robots to deploy power cables between surface assets. This project integrated an onboard RGB-D perception system on the K10-Mini rover using a Jetson AGX Orin, Intel RealSense D415 [2], and ROS 2 Jazzy [3]. AprilTags [1] provide relative target range and bearing, while YOLO11 [4] detections fused with depth estimate the 3D position of nearby rocks. These outputs are published through ROS 2 and displayed in a live operator HUD.

OBJECTIVES

Estimate AprilTag [1] range and bearing to cable-deployment targets
Detect rocks and estimate their 3D position using YOLO11 [4] and depth
Publish perception outputs through ROS 2 [3] for guidance and monitoring

CAMERA MOUNT & GEOMETRY

Camera height: 256 mm · Tilt: 7° downward · Vertical FOV: 40° · Blind zone: ≈0.5 m



100 mm mast
Short profile reduces vibration and camera wobble.

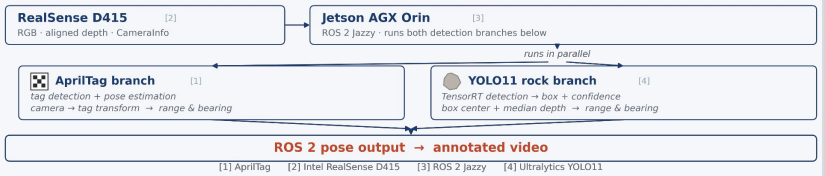
7° downward tilt
Balances near-ground visibility with a visible horizon.

M3 heat-set inserts
Provide durable threads for repeated assembly.

Cable-routing notch
Preserves the rover's existing USB cable path.

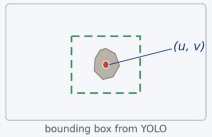
The camera mount was designed to observe both nearby terrain hazards and farther cable-deployment targets.

SYSTEM OVERVIEW



METHODS & KEY EQUATIONS

① Locate the rock
where it is in the camera image

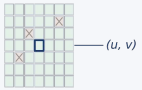


bounding box from YOLO

(u, v) = center of the box

midpoint of the box's corners

② Measure the depth
how far away that point is



7×7 patch of depth pixels
valid reading no reading (ignored)

d = median of the valid pixels

throws out zero / noisy readings

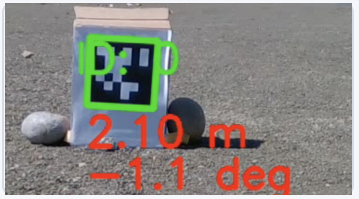
③ Find range & bearing
turns X, Y, Z into distance + angle

$R = \sqrt{X^2 + Y^2 + Z^2}$
straight-line distance to the rock
$\theta = \text{atan2}(X, Z)$
bearing angle (left / right)
using: $X = \frac{(u - c_x)d}{f_x}$ $Y = \frac{(v - c_y)d}{f_y}$ $Z = d$

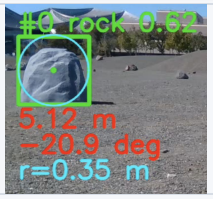
AprilTag calculates X, Y, Z itself
its library runs its own algorithm to get X, Y, Z — then we do step 3

c_x, c_y = image center (pixels) f_x, f_y = focal length (pixels) — both come from the camera's calibration

OPERATOR HUD OUTPUTS



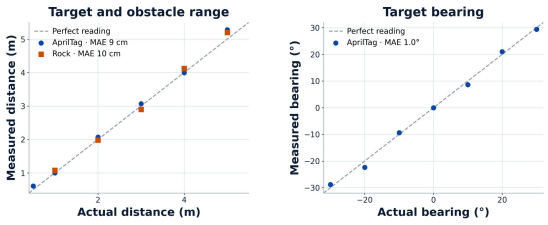
AprilTag [1] target localization with reported range and bearing



YOLO11 [4] rock detection fused with RealSense depth [2]

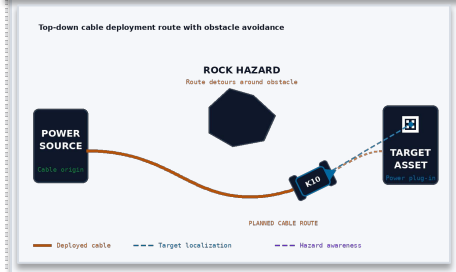
The HUD was used during field testing to verify detections and pose estimates in real time.

VALIDATION



Ground truth was measured manually, and rover outputs were averaged over stationary test segments. Mean absolute errors were 0.10 m for rock range, 0.08 m for AprilTag range, and 1.03° for AprilTag bearing across the tested ±30° range.

MISSION CONTEXT



K10-Mini is being evaluated as a micro-rover for power-cable deployment between a power source and remote asset. Its onboard perception provides target localization and obstacle awareness during integrated testing.

Top-down cable-deployment context showing a power source, target asset, illustrative cable route, target localization, and obstacle awareness.

CONCLUSIONS

Deployed a complete RGB-D perception pipeline onboard K10-Mini
Localized marked deployment targets using AprilTag [1] range and bearing
Estimated 3D rock positions using YOLO11 [4] fused with RealSense depth [2]
Published perception outputs through ROS 2 [3] and displayed them in a live HUD
Established a perception foundation for future cable-deployment guidance

REFERENCES

[1] E. Olson, "AprilTag: A robust and flexible visual fiducial system," in *Proc. 2011 IEEE Int. Conf. Robot. Autom. (ICRA)*, Shanghai, China, 2011, pp. 3400–3407, doi: 10.1109/ICRA.2011.5979561.
[2] L. Keselman, J. I. Woodfill, A. Grunnet-Jepsen, and A. Bhowmik, "Intel RealSense stereoscopic depth cameras," in *Proc. 2017 IEEE Conf. Comput. Vis. Pattern Recognit. Workshops (CVPRW)*, Honolulu, HI, USA, 2017, pp. 1267–1276, doi: 10.1109/CVPRW.2017.167.
[3] S. Macenski, T. Foote, B. Gerkey, C. Lalancette, and W. Woodall, "Robot Operating System 2: Design, architecture, and uses in the wild," *Sci. Robot.*, vol. 7, no. 66, Art. no. eabm6074, May 2022, doi: 10.1126/scirobotics.abm6074.
[4] G. Jocher, J. Qiu, and A. Chaurasia, "Ultralytics YOLO", version 8.0.0, computer software, Ultralytics, Jan. 10, 2023.

Acknowledgements

The author would like to thank Dr. Brian Coltin and Dr. Uland Wong for their mentorship and technical guidance throughout the summer, as well as the members of the Intelligent Robotics Group at NASA Ames Research Center for their support and feedback. The author also gratefully acknowledges NASA OSTEM and the California Space Grant Consortium for providing the opportunity and funding that made this internship happen.