NC STATE UNIVERSITY

SAFE & EFFICIENT EXCAVATION

Automating Utility Detection and Marking for Construction

KEAGAN VARGO

Master of Industrial Design College of Design Spring 2023 ksvargo@ncsu.edu

CONTEXT

Insufficient excavation practices persist as the primary root cause of damages in the U.S.

billion in U.S. annual societal costs due to damaged buried utilities was estimated by the 2019 DIRT report.

17K reports of excavators failing to maintain clearance after verifying marks

33% of professional excavators said locating issues are the leading cause of damage to underground utilities

41,446 incidents caused by excavators digging prior to verifying marks

PROBLEM STATEMENT

Excavator operators digging around existing in-ground lines need a better way to detect and record obstacles before and during operation to while planing dig sites to safely optimize work flow.

METHODS

Through communicating with excavator operators, researching technology innovation, and prototyping a better understanding of the necessary services was identified.

Surveys and interviews with surveyors and excavator operators where used to begin gathering pain points, observations and surveys were used to gain insights. A private excavator group was used along with other methods to grow and validate research

CURRENT WORKFLOW

Call 811



Locate Utilities



Mark Surface

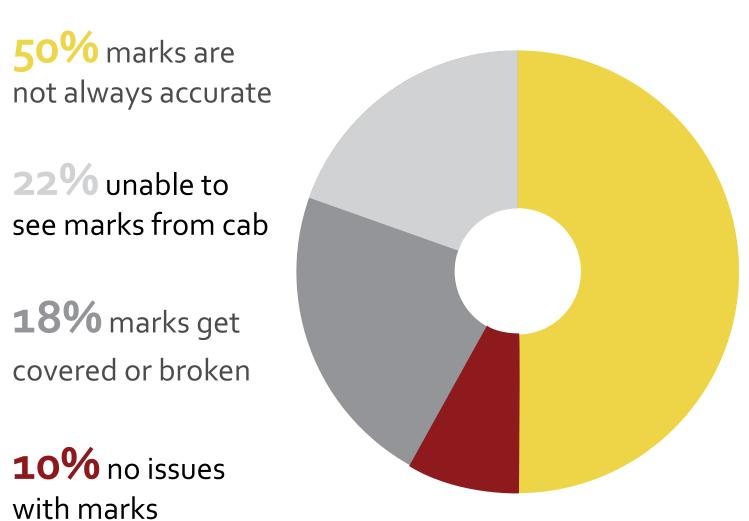


Manually Avoid



VOICE OF THE OPERATOR

What is this biggest challenge with following the markings left by surveyors?





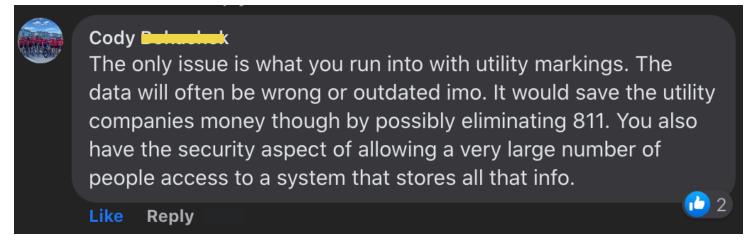
Surveys **19**

Interviews 13

100% respondents believe visualizing collected utility data would be useful inside the cab of the excavator

However

26% would only be willing to perform their own utility survey during the utility companies marking window



One operator stated he was in an ongoing lawsuit with a utility company over **liability** of a miss marked utility that was hit

Another operator had **stopped digging**, stating he had just hit a water line moments before

TECHNOLOGY INNOVATION

Surveyors have cutting edge locating technologies

Locators use **Ground Penetrating Radar** in tandem with Global Positioning Systems to allow surveyors to collect utility data and display it spatially





INSIGHTS - CONCEPT

The majority of utility collisions come from unmarked/missed marks line, this is out of the control of the operator.

Ensure safe digging by scan - dig principle

Slow point is manual digging/hydro vac around utilities

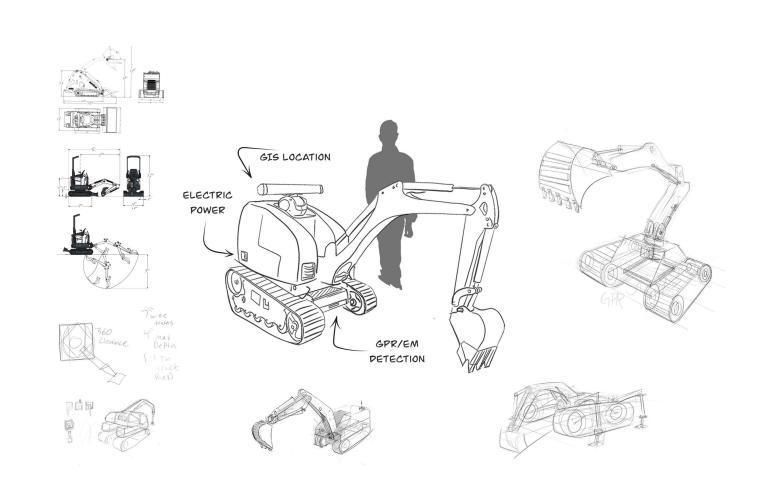
Confidently increase area of excavation

A base station is necessary for accurate location triangulation between utility detection and excavation

Scan and digging on same machine.

Utility detection must happen in front of excavation operations

Utility detection on-board excavator is not feasible.



INTERPRET

COLLECT & MARK

01 Set up base station

05 Monitor and filter GPS position & freq data via Python pyserial

02 Drive 'Excavator Bot' to 4 corners creating bounding box

03 Bot scans area, detects freq spikes, marks/plots coordinates

04 Freq & GPS position are output via Arduino BT serial monitor

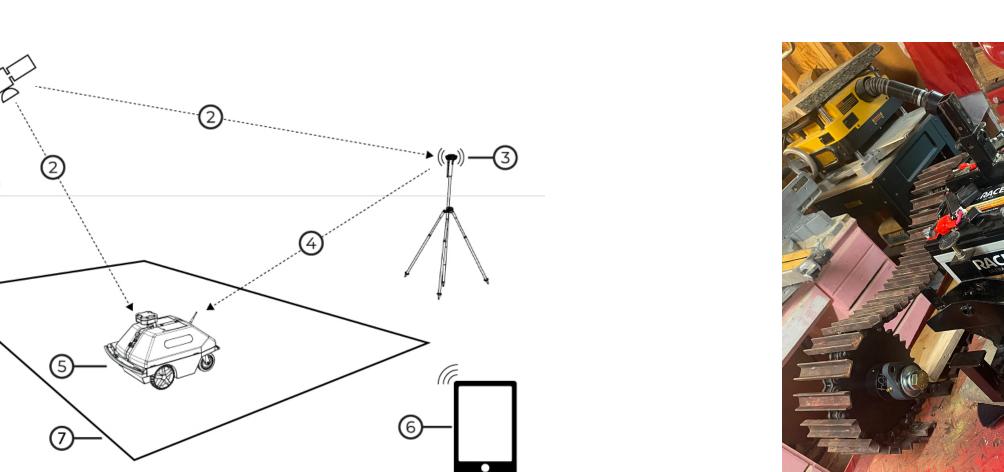
06 Plot Freq spikes via python using freq filter

PROTOTYPE WORKFLOW

- **07** Create virtual utility map via GPS data min/max
- **08** Reference plot data from bot to display in excavator

DISPLAY

- **09** Cross reference dig path on excavator display
- **10** Excavator relates dig position to marked utilities
- **11** Alert gives notification when close
- 12 Utility locations are stored for legal documentation



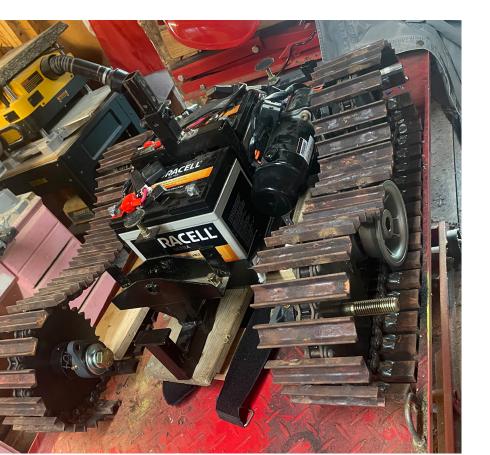




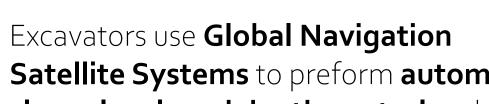












Excavators continue to gain

new automated technologies

Satellite Systems to preform automatic slope, level, and depth control and real time cut/fill indications using GNSS data

REFERENCES

Naghshbandi, S. N., Varga, L., & Hu, Y. (2021). Technologies for safe and resilient earthmoving operations: A systematic literature review. Automation in Construction, 125, 103632

CGA, (2019). Data-Informed Insights and Recommendations for More Effective Excavator Outreach, CGA White Papers, (1-18)

S. Talmaki, V.R. Kamat, (2014) Real-time hybrid virtuality for prevention of excavation related utility strikes, J. Comput. Civ. Eng. 28 (3).

CRITERIA

- Remote Utility Detection
- Precise Automated Marking
- Ensure Accurate Dig Area • Mark Dig Paths
- Safe for Ground Workers