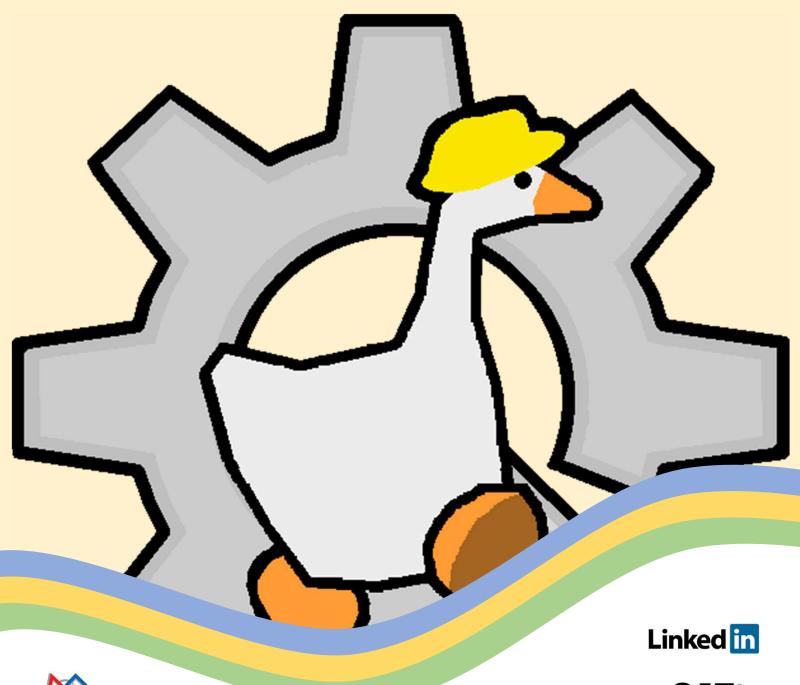
# FTC QUACKOLOGY 19508





















# **MEET OUR TEAM**



(Left to right) Back: Vick, Ian, Yutian, Andrew, Mark, Eddy, Alec. Front: Andy, Lucas, Kenny, Grace. Shot in front of US Engineering League (USEL) facility.

# Team Roles

### Hardware:

Andy, Alec, Kenny, Ian

### CAD:

Andrew, Ian, Mark, Grace, Alec

# **Captains:**

Andrew,

### **Software:**

Vick, Eddy, Ian, Lucas

### **Outreach:**

Andrew, Yutian, Ian, Grace

# **Team Info**

Team 19508 Quackology was founded in 2021 during the FTC Freight Frenzy season. Our home facility is at the USEL center, which we share with our sibling team 11392 Defenestration.

# **Mission**

Our goal is to facilitate a learning environment for members to pursue hardware, software, and business-related components of robotics, as well as to spread the good word of FIRST programs through community events and forge connections in our local municipalities.

# **TEAM PLAN**

# Recruitment

We recruit new members from doing **outreach events** in the community, such as the summer camps we host. Our plan for rookie members involves giving them as much **hands-on experience** as possible during the off-season.

# **Financing**

- Support local organizations through sponsorship deals
- Email for external sponsorship opportunities
- Use community connections for sponsoring

















# Goals

### Robot Community Team Reach 5,000 **Implement Recruit 2** people Roadrunner. people 500 hours of April Tag. Reach state community competition Sensor **Filtering** outreach **Organize team Develop team** Attend 5 structure events strategy

# **Year in Review**

We were able to **reach** all our goals (except for reaching the state competition) so far. We **exceeded our community goals** and recruited **twice as many new members**, and were able to implement the desired concepts onto our new robot design.

# **MOTIVATING THE COMMUNITY**

We made 9,000+ impacts through outreach events like workshops, camps, and social media.

# π Day: Meadow Glens Elementary

We held a station where we showed our robot to the elementary school students and described FIRST programs. Additionally, we talked to Congressman **Bill Foster**. 200+ participants



# **Block Party:** Arabian Avenue, Naperville

We showcased our robot and **filmed a news segment** about FIRST for **NCTV17**. We also met the mayor of Naperville, **Scott Wehrli**, and city councilman **Paul Leong**. 100+ visitors.



# Summer Camp: USEL Center, Naperville

We hosted a camp for middle-schoolers. We taught robot fundamentals, designed a mock-competition, and spread information about FIRST. We recruited **2 new members** through our camp.



# Robot Workshop: USEL Center, Naperville We hosted a free workshop for community members, particularly younger students, to come explore robotics and learn about software, hardware, as well as the FIRST robotics programs. (15+ students)

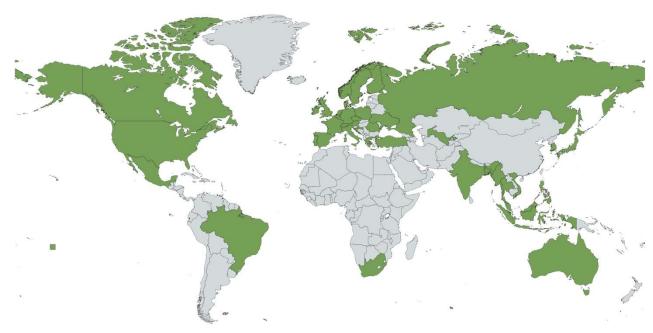


# **Sumobot Competitions: Naperville**

We helped USEL administer Sumobot competitions by mentoring participants on robot construction and refereeing the matches. In total, we were able to reach over 500+ students and parents.



# **Social Media**



The 40 countries in green represent where our videos have been viewed.



# **The Comments Section**

Nice!
- Team 19477
Bit-by-Bit

Thank you very much!
@mohamedabdahamed7099

I love this! @JoshuaThe-xp2jb

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# FORGING CONNECTIONS

We converged with city officials and career professionals on topics involving education and FIRST.



### Jian Sun (Engineering, Panduit)

Coach Sun provided his mechanical expertise to guide our hardware design with stringing the pulley design. He has also helped organize team events and mentor rookies.



### Fred Xu (Project Management, Abbot)

Coach Fred has assisted the team with lessons on data collection and analysis to foster discussions of game strategy and development.



### Bing Zhong (Sr. Design Eng.)

Coach Bing used his career experience to mentor the CAD team in their productions. He gave us tips on how to design our drone launcher.



### Scott Wehrli (Mayor of Naperville)

Mr. Wehrli was at the Block Party and was a part of our discussion with Mr. Leong on STEM education and its future with robotics.



### Paul Leong (Naperville City Council)

We met former 203 School Board member and current city councilman Paul Leong at the Block Party, where he taught about applications of robotics education.



### Bill Foster (Representative, IL 11th Dist.)

Mr. Foster is the only PhD physicist in Congress. We had 2 meetings with Mr. Foster, where we showcased our design and learned from his career at Fermilab.



### FIRST Tech Challenge Illinois

We reached out to FTC Illinois and they supported us by providing us with minibots to utilize for more interactive demonstrations in our workshops and our summer camp.



### 18149 Cybernetic Squirrels & 19652 7ech!neers

We connected with local teams 18149 Cybernetic Squirrels and 19652 7ech!neers at a scrimmage that we hosted to collaborate on game strategies, form relations, and prepare for upcoming meets.

# **CONTROLLING AUTO**

We implemented and integrated new systems into our autonomous to provide efficient movement.

# **ORB Detection**

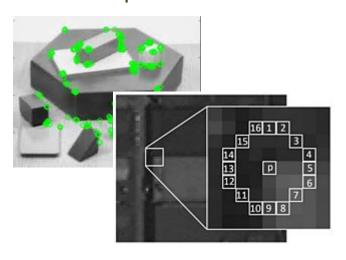
**Oriented FAST and Rotated BRIEF** 

FAST: Corner detection algorithm

 Analyzing intensity differences in randomized circle

BRIEF: Descriptor for feature point

 Convert keypoint to binary vector, reduce noise with Gaussian blurring



# $\{F\}$ fixed camera $\{F\}$ fixed camera $\{F\}$ fixed camera $\{F\}$ fixed camera $\{C\}$ camera on robot $\{C\}$ camera on robot

# **AprilTag**Relative positioning with tags

- Utilized the Lie group SE(3) to represent transformations
- Transformed relative position to global position

# Roadrunner

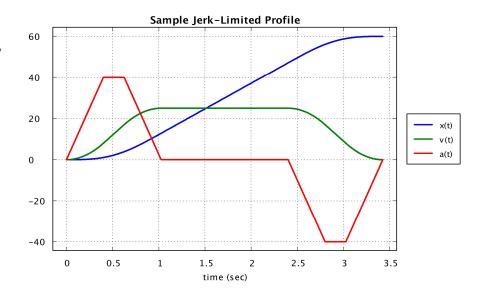
frame

### Pathmaking with odometry

Our robot uses 3 odometry wheels for maximum accuracy.

### **GENERAL ACTIONS**

- Feedforward loops
   estimate amount of power
   needed to reach a location.
- **Feedback loops** calculate and correct errors.
- Mecanum kinematics manipulate the forces of mecanum wheels to create desired movement.
- Splines facilitate quick, smooth, and continuous movement.



Example of basic motion-planning, v0 being actual

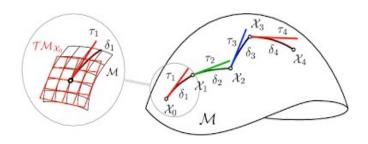
# THINKING BEYOND

In order to refine our software, we integrated advanced mathematical and scientific concepts.

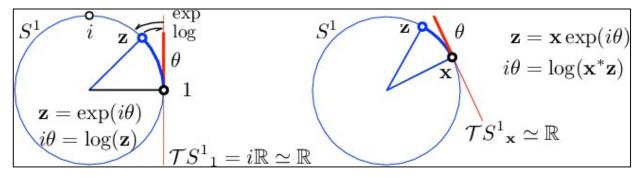
# Lie Theory

### Relating linear space to nonlinear

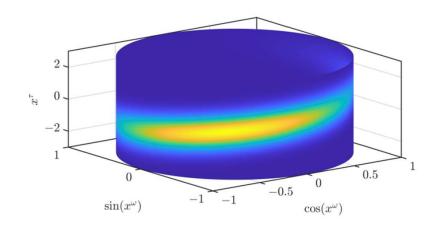
- Respects symmetries of the topology of the space
- Encapsulates differential motion in manifold space
- Utilized SO(2), SO(3), SE(2), SE(3) groups
- We use it to represent pose and motion of the robot



3D manifold is mapped onto linear plane.



Lie theory maps nonlinear manifold space onto linear vector space.



Representation of x and heading elements of SE(2)'s state space.\*

# SE(2) State Space

The SE(2) Lie group represents **transformations in 2D space** (ex: rotations and translations).

Each point in this space represents a possible pose. The probability density is represented by color (yellow represents more likely).

<sup>\*</sup>Pfaff, F., Li, K., & Hanebeck, U. D. (2021). The State Space Subdivision Filter for Estimation on SE(2). Sensors (Basel, Switzerland), 21(18), 6314. https://doi.org/10.3390/s21186314

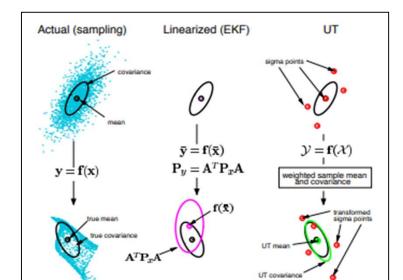
# **Bayesian Filtering**

### Prior and posterior robot pose estimation

Kalman Filter	UKF	EKF	UKFM	IEKF	S3F (SE2)	Particle Filter
•Linear •Unimodal •Deterministic •Static accuracy	•Non-linear •Unimodal •Deterministic •Static accuracy •Tuning parameters •Sampling	•Non-linear Unimodal •Deterministic •Static Accuracy	•Non-linear •Unimodal •Deterministic •Static accuracy •Act on Manifolds •Tuning parameters •Sampling	•Non-linear Unimodal •Deterministic •Static Accuracy •Act on Manifolds	•Non-linear Unimodal •Deterministic •Improvable Accuracy •Act on Manifolds •Sampling	•Non-linear Multimodal •Randomness •Improvable Accuracy •Act on Manifolds •Sampling

Systems are listed in order of least accurate to most accurate (least time complexity to most time complexity).

### Accuracy



# **Square Root UKF**

**UKF** relies on deterministic sampling: state x, covariance  $\Omega$ .

Sample  $x_i = x + R_i$  where subscript i represents the column and  $R * R^T = \Omega$ .

R is calculated through the Cholesky Decomposition which is susceptible to **numeric instability** (e.g. rounding).

# **Time Complexity**

# UKF vs EKF vs UKFM vs IEKF

**UKF, EKF:** Nonlinear variation of Kalman filter – same performance.

**UKF, UKFM:** Approximates the gaussian by linearizing the gaussian of a sample propagated through nonlinear function.

**EKF, IEKF:** Approximates nonlinear propagation function by linearizing as a Jacobian.

**UKFM, IEKF:** Act on Lie groups, respects symmetries of state space topology.

$$\Omega_{t+1} = \sum (x_i - \bar{x})(x_i - \bar{x})^T$$

$$\begin{bmatrix} \sqrt{A} \\ \sqrt{B} \end{bmatrix} = \text{QR} \quad \sqrt{A + B} = R$$

$$\begin{bmatrix} \sqrt{A}\sqrt{B} \end{bmatrix} \begin{bmatrix} \sqrt{A} \\ \sqrt{B} \end{bmatrix} = A + B$$

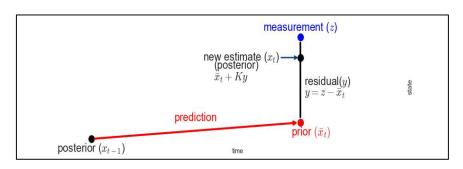
$$= R^T Q^T Q R$$

$$= R^T R$$

By propagating the square root of the covariance and calculating it directly from the sample, we can avoid the Cholesky Decomposition, providing greater stability.

# **UKF vs UKFM**

### Unscented Kalman Filter vs Unscented Kalman Filter on Manifolds



Kalman filters approximate the true mean by comparing the prior and measurement based off of reliability.

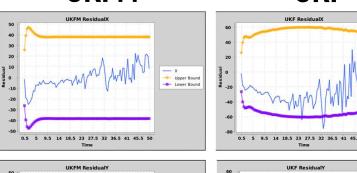
Ultimately, we had to choose between **UKF** and **UKFM** for our filter, based on accuracy and time complexities.

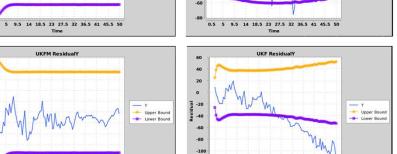
• UKF did not respect topology of rotations; captured error incorrectly

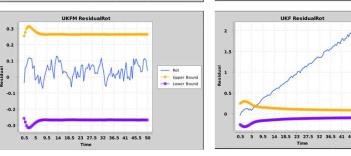
# **UKFM**

0.5 5 9.5 14 18.5 23 27.5 32 36.5 41 45.5

# UKF









### **UKFM:**

- Stable
- Errors are wellaccounted for by standard error estimation

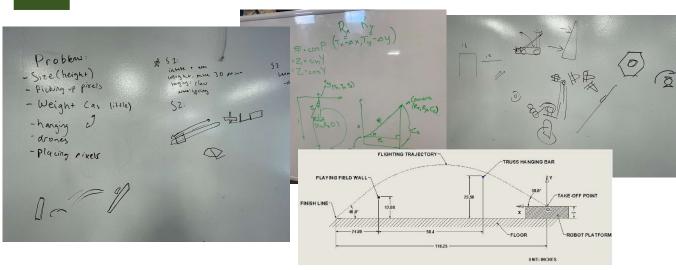
### **UKM:**

- Unstable
- Diverging from true path
- Errors are not accounted for by the standard error estimation

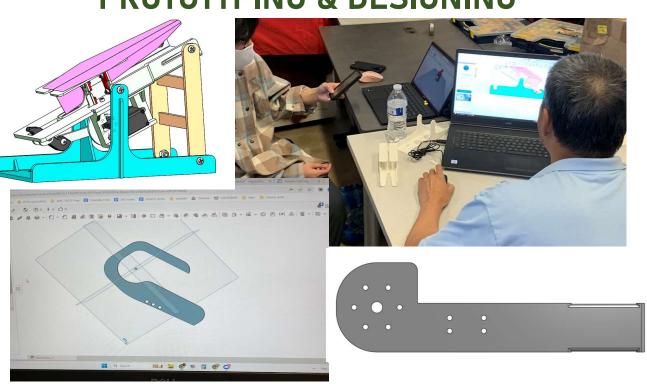
Due to the benefits of **UKFM**, we chose this variation over the standard **UKF**.

# INNOVATING THE FUTURE

We underwent many iterations to improve our claw, pulley, drone launcher, and other designs.



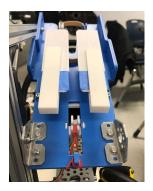
# **PROTOTYPING & DESIGNING**



# **TESTING & BUILDING**

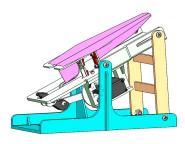






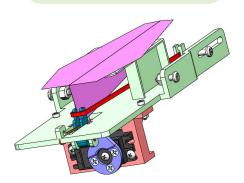
**ITERATIONS** 

# **Drone Launcher**



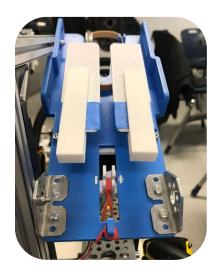
### Iteration 1:

- Large base
- Unreliable trigger



# **Iteration 2:**

- New mountTrigger
  - perpendicular to servo (more reliable)



# Claw



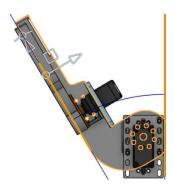
### Iteration 1:

- Unstable servo connection
  - Long print time



# **Iteration 2:**

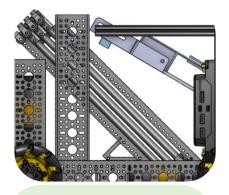
- Limited range of motion
- Servo unstable (no box)



### **Iteration 3:**

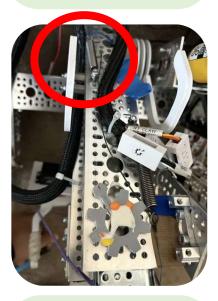
- Servo box
- Full range of motion
- Stable build

# **Pulley**



## **Iteration 1:**

- Slight tilt to right
- Weak lifting
- No hanging mechanism
- Pulley string loose



# **Iteration 2:**

- Added tension string to counteract pulley
  - Added hook for hanging
- Added custom string wheel to stabilize

# **DESIGNING WITH CAD**

We used Onshape to design custom and efficient parts to bolster our robot.

# **Drone Launcher**

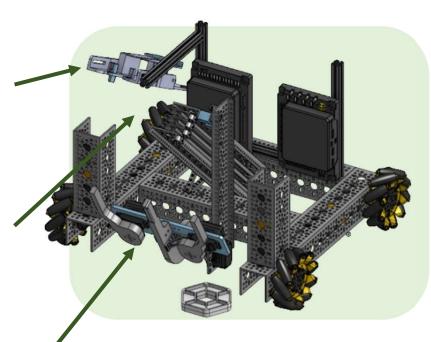
Our drone launcher uses a rubber-band and servo powered trigger to launch custom drone designs.

# **Pulley**

The pulley has two strings running antiparallel to provide stability. Additionally, custom hooks allow it to be used for hanging.

# Claw

The trident design allows the intaking of two pixels at once. Additionally, the servo's range allows a larger intake size to guarantee picking up pixels.



### Other features:

**Camera:** Our robot features a Logitech C920 webcam for a wider detection frame in auto. **Drivetrain:** We use mecanum wheels for full range of motion.

**Motors:** Our motors are mounted to provide as much space as possible (some are vertical, and all are within the chassis).

**Clearance:** Our robot is designed to be low enough to pass through the truss gate.

# **Holes on Purpose**

The holes in our design not only provide extra screw-fastening locations but actually provide more strength to the claw. Outside-facing edges are printed extra-thick, so holes act like pillars to strengthen the overall claw.

