E-Kart

Electric GoKart and Outreach Project Definition

ELECTRICAL AND COMPUTER ENGINEERING
COLORADO STATE UNIVERSITY

Electrical Engineering:
Jeremy Griess, Thomas Balzer, Morgan Heacox, Muath Alotaibi

Computer Engineering:
Christian Castillo, Spencer Beer

Mechanical Engineering
Ryan Calzone, Cali Clark

Vertically Integrated Program Students
Alex Vandeburgt

Supervising Professor
Olivera Notaros

Engineer in Residence
Doug Bartlett

Summary

We are a team of electrical, computer, and mechanical engineers who are using modern technologies to showcase high levels of applied fundamental problem solving to prospective students. The highly technical Ekart demonstrates the seamless integration of various core concepts from each of the engineering departments. The electrical engineers incorporate their skills of wiring and coding to the cart through the addition of electric powered motors that are controlled using python. The computer engineers bring new and improved topics like integrating machine learning with autonomous pedestrian recognition. The computer engineers and electrical engineers work closely together to ensure successful communication between the computer and the components of the cart. The mechanicals bring their experience of design and machining to create a stable body to house the electrical and computer components. Mechanicals also assemble the cart to improve the overall functionality and aesthetic of the electric cart. Together, all of the engineering concentrations work together to ensure the safety of both the cart and the rider. With no specific instruction as to what needs to be completed on the cart the team plans on increasing the safety and fun factors with the hope of encouraging future generations to get excited about engineering.

Definition

The E-Kart is a continuing senior design project using electric motors to power a kart completely built by the students. Combining the abilities of Electrical, Computer, and Mechanical engineers our goal is to improve upon different aspects of the Kart and keep the motors working. The Kart will also assist in presentations on STEM for kids and college students alike to engage and excite them about the possibilities of working in STEM professionally.

Importance

This is an ECE Outreach project meant to showcase some of the capabilities of engineering to potential future students. The E-kart contains various examples of how different engineering fields come together in order to create a functioning machine. Seeing how these different expertises are implemented together may inspire or spark interest in those who are considering engineering as a career path. This project has the capability of catching the eye of people from elementary school up to high school and beyond.

Revision History

Date	Comments	Version	Approved by
9/22	**Initial Document**	**1.0**	

Problem Statement

The 2023-2024 E-Kart team is tasked with updating and improving the past generations version of the E-Kart by integrating new technologies and upgrading the current mechanical systems. We will diligently work to build the best working model of the engineering principles that we will be able to show off to outreach events. Our main focus is to keep people intrigued so many different concepts but nothing that we will take to the commercial level.

Electrical Engineering Objectives

The electrical engineers will aim to fix non functioning components that were previously being used on the kart and also implementing some new features. First of all, we need to figure out why the right motor is not functioning and get it to be operational again. The kart already has a battery management system (BMS) inside the battery containment shell, but it was fried by the previous team. Instead of attempting to replace it, they connected wiring to each battery, and each battery had to be charged separately through a LiPo battery charger. Our goal this year is to reimplement the BMS such that all the batteries can be charged simultaneously via an outlet power supply. We also want to add headlights and maybe brake lights.

- Make the right motor operational
- Implement BMS that can charge all batteries via a 50.4V outlet power supply.
- Add headlights and maybe brake lights
- Create circuit designs and diagrams for all aspects of the kart and motor controls
- Cable management

Computer Engineering Objectives

The computer engineers will be focusing heavily on the CAN bus this semester, and further improvements on the ML features later. We will also be working with the UI on the dash of the E-Kart: cleaning it up, and making it more functional. Lastly, we need to purchase additional hardware, to possibly improve the ML model, and add positional data to the E-Kart for the purpose of tracking course projections and optimizations. The following are our planned improvements:

- More UI features
- GPS for Route Planning and Optimization
- LiDAR may be added
- ML model is optimized and used for distance detection
- VESC programming and data is understood
- CAN bus communication is upstream and downstream
- Cable management and electronics protections
- Lots of documentation

Mechanical Engineering Objectives

The mechanical engineers are tasked with updating the current mechanical systems, as well as integrating new and innovative features to the kart. The primary focus will be fixing the physical issues actively affecting the kart, this will include the following changes: decreasing the turning radius of the vehicle, improving the effectiveness of the braking system, decreasing the range of motion in the steering wheel, and creating an aerodynamic/aesthetically pleasing exterior. The following are our planned improvements:

- Must fit through a 34” wide door frame
- Brakes discs assembled properly and in correct positions
- Braking calipers used appropriately/evenly for proportional braking speeds
- Shell includes areas for air circulation on the rear for electronics
- Electronics bay should not heat up within more than a couple of degrees hotter than outside temperature
- Steering wheel positioned accessibly for all heights
- Correct measurements taken for mathematics associated with decreasing the turning radius
- Final turning radius to be at least 5 degrees of freedom more than previous design
- Shell design considers aerodynamic properties to decrease drag coefficient of kart
- Shell has manageable weight and size, staying within the tested range of less than 300 lbs
- Shell is easy to disassemble
- Shell has designed hole to observe the electronics when fully assembled

Electrical Engineering Research

The electrical engineering team will research a robust battery management design that will ensure the carts ability to charge safely and efficiently for constant operation and testing of the Ekart. The vesc motor controllers have a built in regenerative braking feature that needs research to operate and requires specific current limitations to work safely and effectively.

Computer Engineering Research

The computer engineering team will research how to communicate between the raspberry pi and the CAN bus, The machine learning model, and overall features through hardware and software will be researched:

- Adding UI Features:
  - Ability to use reverse switch
  - Use GPS and VESC data to produce a more accurate speed with a tolerance of 2 mph
  - Able to control lights through dashboard
  - Reverse camera has image detection
  - Button for GPS navigation system
- GPS for Route Planning and Optimization
  - Integrate ML with GPS for best route projections along a predetermined route. Used in training drivers and completing routes or courses efficiently.
  - Integrate with Google Maps API
- LiDAR
  - Detect objects from at least 30 feet
  - Real-time LiDAR detection
  - Works well or is well documented with Raspberry Pi 4 / Python
- ML model
  - Optimize for efficiency on Raspberry Pi 4 so that there's no latency issues and smaller energy consumption from the model (MobileNetv2)
  - Detect distance from camera to object
  - Shoot for a 90% accuracy on the object detection
- VESC
  - Ensure regenerative braking functionality
  - Ensure maximum recorded speed can be achieved (~40 MPH)
- CAN
  - Interpret and understand the data being sent **to** the Raspberry Pi
  - Add the ability to send CAN data **from** the Raspberry Pi
- Documentation
  - Ensure WiKi's are on each repo

Mechanical Engineering Research

The mechanical engineering team will research all parts of the current mechanical systems and past iterations of the kart. This research will decide what needs to be fixed/updated and how these tasks will be completed. This will also help in deciding which parts must be refabricated, reused, or purchased for optimal budgeting and effectiveness of the kart. In the later part of the semester preliminary research for the shell will be completed in preparation for design and manufacturing.

Preliminary Requirements

1. Kart Shell

Protect and cover electronics and fragile components

Improve the vehicle's aerodynamics by, for instance, lowering air resistance.

2. Enhance Acceleration:

Regulating the throttle response for quicker acceleration.

Making sure the vehicle's weight distribution is balanced for better performance.

3. Extend Range:

Making sure the tires are properly inflated to reduce rolling resistance.

5. User Experience:

Improving the dashboard with user-friendly controls.

6. Aesthetics:

Applying new paint or decals to give a unique design on the car.

Installing LED lighting kits to add style.

7. Accessibility:

Offering adjustable seating and controls to accommodate users of different sizes.

Making sure an ease of entry and exit for all users.

Budget Justification

We do not currently know how much money is left over from last year's team, so right now we are only considering our ECE Department supplied budget of $1600 ($200 per senior member). We are planning on buying a couple of new items like the TF-Luna, GPS module, and bms module. The mechanicals are planning to buy A new steering wheel axel, and building and painting the shell.

Process Step	Potential Failure Mode	Potential Failure Effect	SEV1	Potential Causes	OCC2	Current Process Controls	DET3	RPN4	Action Recommended
What is the step?	In what ways can step go wrong?	What is the impact on the customer if the failure mode is not prevented or corrected?	How severe is the effect on the customer?	What causes the step to go wrong (i.e. how could the failure mode occur)?	How frequently is the cause likely to occur?	What are the existing controls that either prevent the failure mode from occuring or detect it should it occur?	How probable is detection of the failure mode or its cause?	Risk priority number pcalculated as SEV x OCC x DET	What are the actions for reducing the occurrence of the causes or for improving its detection? Provide actions on high RPNs and on severity ratings of 9 or 10
Start the Kart	motor doesnt turn	Kart doesnt move	10	Can bus failure, motor controller shortage, wiring disconected	4	correctly soldered parts, vesc troubleshooting	1	40	bondic wires together
	Pedal disconects	Kart doesnt move	10	Wiring shorts, parts disconnect	2	Heat shrink connectors, Bondic	1	20	heat shrink and bondic
Charging	Battery Failure	Fire. Batteries explode.	7	Incorrect charging method. Overcharging /Unregulated charging.	2	C240 Smart Charger, but requires 24/7 monitoring	3	42	Battery/ESC/Motor setup has better cable management and dedicated charging mode.
Raspberry pi	can bus doesnt connect	UI will not load	4	Poor physical connection, issue from either motor controller	2	It will not turn on if the can bus is not linked with each other. another good sign is the motors	3	24	

						arent linked together			
	Camera doesnt connect	The UI may load but our model doesnt	6	Poor connections, code is not run properly	5	Raspberry pi are pre programmed, you will know if the camera doesnt turn on	2	60	Make sure the bash script will always load. Backup micro-sd to plug and play
	Machine learning model doesnt stop the vehicle	They crash into a pedestrian	9	Model doesnt recognize the human or the depth of the human	3	Model is pre trained and trained to detect people more often than not	3	81	Extensive testing on the model and the vehicle before deployment in school demo
Full Speed	Breaks stop working	Will not be able to stop Kart	10	The break pressure isnt set correctly	4	Safety testings and pressure gauges	3	120	Breaks tests periodically. Make sure we can stop on a dime
	Motor contoller wrong amount of current	The speedometer will be set incorrectly	6	Motor controllers are reading the wrong currents	2	vesc testing, physcial speedometer	6	72	Always test the speedometer with a physical and the virtual. Double check the current limiter

Mechanical Engineering FMEA:

Process Step	Potential Failure Mode	Potenetial Failure Effect	SEV1	Potential Causes	OCC2	Current Process Controls	DET3	RPN4	Action Recommended
What is the step?	In what ways can step go wrong?	What is the impact on the customer if the failure mode is not prevented or corrected?	How severe is the effect on the customer?	What causes the step to go wrong (i.e. how could the failure mode occur)?	How frequently is the cause likely to occur?	What are the existing controls that either prevent the failure mode from occuring or detect it should it occur?	How probabale is detection of the failure mode or its cause?	Risk priority number calculated as SEV x OCC x DET	What are the actions for reducing the occurrence of the causes or for improving its detection? Provide actions on high RPNs and on severity ratings of 9 or 10
Driving Kart	Frame bends	Inconvenience and possible unusable condition	8	Overweight load or design failure for structural strength	1	FEA analysis and checking welds before driving	1	8	N/A
	Shell falls apart	User could be injured and kart can be damaged	7	Poor construction, poor adhesive, or driving after crash	1	Test shell durability before test drives and make sure adhesive is not expired	2	14	Detailed solidworks model of shell and checking materials are up to date and are correct for the job
	Electronics over heat	Kart catches on fire and electronics damaged	7	Shell restricts airflow to electronics	1	Design shell to have ventilation	3	21	Check on electronics throughout initial test rides for overheating
Stopping/ Braking Kart	Kart doesn't stop	Irritation of a failed function	3	Mechanical disconnection, brake placement	6	Turn-key operation. Ensure power supply prior to use	7	126	Perform a pre-use equipment check
	Kart doesn't stop	Users and bystanders at risk of injury	10	Mechanical disconnection in braking system	2	Emergency Shut off	7	140	Detailed and quality research on purchased parts and better design implementation
	Hydrolic lines not fully bled	Slow stopping speeds	5	Design failure in structure	1	Test braking system in controlled enviroment prior to use	6	30	Test hydrolic braking cycle, update mounting location of lines
	Pedal breaks off / doesnt respond efficiently	Possible injury if kart is in motion	6	Design failure in structure	2	Test braking system in controlled enviroment prior to use	3	36	Secure braking mount and update any parts that failed and/or broke
Steer Kart	Kart doesn't turn after updates were made	User won't be able to make turns	7	Mechanical disconnection in steering system	2	None	5	70	Adjust changes made and research better methods
	Steering component fails	User and bystanders at risk of injury	9	Mechanical disconnection in steering system	3	None	3	81	Detailed and quality research on purchased parts and design implementation of the parts
Starting Kart	Motors don't run	Users don't experiance what they came for	7	Electrical/ Mechanical disconnection	4	Turn kart on and test acceleration pedal	1	28	Check wiring and system setups
	Axels don't rotate	User won't be able to run kart	7	Chain tensions, or disconnection to motors	2	Part check during assembly, initial testing	3	42	During assembly ensure parts are positioned correctly, research motor chains

Computer and Electrical Engineering Risk And Reliability Assesment:

#	Risk Event	Probability/100	Impact, weeks	Score, hours	Effect	Risk Mitigation Plan	Person responsible for implementing control
1	VESC burns out	30	2	30	Delay, Cost, and Injury	VESC well cooled	Christian and Spencer
2	BMS burns out	30	2	100	Delay, Cost, and Injury	BMS needs to support 44.4 V	CE and EE Team
3	APD doesn't detect pedestrians	50	2	20	Delay, Cost, and Injury	Improve ML model and integrate LiDAR	Christian and Spencer
4	CAN bus failure	10	3	20	Delay, Cost	Anomoly detection	Christian and Spencer
				Total risk :	Delay, Cost, and Injury	Mainting code and double checking components	

Mechanical Engineering Risk And Reliability Assesment:

#	Risk Event	Probability/100	Impact, weeks	Score, hours	Effect	Risk Mitigation Plan	Person responsible for implementing control
1	Shell Breaks Apart	30	2	20	Delay	Check over shell before use	Ryan and Cali
2	Frame Bends	20	3	30	Delay, Cost, and Injury	Visually inspect kart before use and when rider first gets in	Ryan and Cali
3	Brakes Fail	20	1	2	Delay and Injury	Have new brakes on standby and test brakes before ride	Ryan and Cali
4	Steering Components Fail	10	1	2	Delay, Cost, and Injury	Test steering before driving	Ryan and Cali
5	Electronics Overheat	30	3	10	Delay and Cost	Continoulsy check electronics during pauses in ride	Ryan and Cali
				Total risk :	Delay, Cost, and Injury	Always double checking compenents before and between rides	

**The above
data is part of the full list and is included as initial consideration**

Computer Engineering Timeline:

Computer Engineering Timeline			
Task	**Date Start**	**Date End**	**Team Member**
Brainstorming ideas	8/26	9/20	
Get Kart running again	9/26	9/15	
Order necessary parts	9/20	10/6	
Connect raspberry pi to rear camera	9/20	10/6	All
Impliment Reverse Functionality into UI	10/6	10/13	All
Add APD functionality to Rear Cam	10/13	10/20	All
Impliment automatic switching between front and rear with CAN	10/20	10/6	All
Add LiDAR/GPS to raspberry pi	10/6	10/27	Spencer
Learn how to use Qt and set up UI	10/27	10/27	All
Ensure cross functionality with APD and LiDAR/GPS	10/27	11/3	Spencer
Set up off-kart programming environment (with touchscreen and RPi4)	11/3	11/3	Christian
Work on Qt UI to display flash warning	11/3	11/10	Christian
Settings for Analog vs Digital speedometer	11/10	11/10	Spencer
Work on adding Piezo Buzzer or another output warning	11/10	11/17	Christian

Warnings for APD system	11/17	11/17	Spencer
Whatever other CAN data we can send over and back to VESC	11/17	12/8	All
Add external features	12/8	1/12	All

Electrical Engineering Timeline:

Electrical Engineering Timeline			
Task	**Date Start**	**Date End**	**Team Member**
Team Budget	NA	NA	All
Ideas for EE	8/21	9/8	All
Parts Research	9/12	9/29	All
Parts Ordering	9/29	10/6	All
ESC Testing	9/12	10/6	All
Motor Testing	9/12	10/6	All
Vesc Research	9/12	10/6	All
BMS Research	9/5	9/15	All
Cable Management	10/10	10/18	All
Regenerative Braking Research	9/20	9/27	All
Replace ESC with Watercooled versions	10/24	11/3	All
Brake and Headlights	10/20	10/27	All
High Voltage Power Management	9/12	10/6	All
Low Voltage Power Management	9/12	10/6	All
BMS integration	9/20	9/27	All
ESC and Motor Testing with new setup	11/3	11/7	All
CAN data transmission	9/12	9/29	All

Motor speed testing	9/15	9/25	All
Cosmetic Lighting	11/6	11/12	All
Final Clean up	12/1	12/15	All

Mechanical Engineering Timeline:

Mechanical Engineering Timeline			
Task	**Date Start**	**Date End**	**Team Member**
Determine what needed to be done with kart	8/30	9/6	All
Research how to decrease steering radius	9/7	9/7	All
Figure out how kart was built in order to take it apart for modification	9/12	9/12	All
Gantt Chart	9/13	9/22	All
QFD	9/13	9/22	All
FMEA/Risk and Reliability	9/15	9/22	All
Trial run kart to take general initial measurements	9/26	9/26	All
Decrease DOF of steering wheel	9/28	10/3	All
Reduce steering wheel size	9/28	10/3	All
Drill holes in existing parts to decrease steering radius	10/5	10/10	All
Take apart axels	10/12	10/19	All
Unweld brake discs and position them correctly	10/24	11/7	All
Reassemble axels	11/9	11/16	All
Start researching and initial concepts for shell	11/28	12/8	All