National Aeronautics and Space Administration

NASA's New York City Research Initiative Collaboration with New Jersey Space Grant

Mid-Atlantic Space Grant Meeting
November 3, 2011

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NASA Education

New York City Research Initiative (NYCRI http://education.gsfc.nasa.gov/nycri)

- **Research teams consisting of:**
  - high school student (grades 10-12)
  - high/middle school teacher (grades 7-12)
  - undergraduate or graduate student

- **Teams are assigned to a Goddard Institute for Space Studies (GISS) scientist or university professor and their graduate students who conduct research related to one of the NASA Directorates (Aeronautics, Human Exploration and Operations; Science).**

- **FY 2011 the NYCRI had 13 teams (16 UG or G students assigned to teams) - 3 teams were assigned an undergraduate or graduate student who was funded by the New Jersey Space Grant Consortium.**

Participating colleges, include:

- City University of New York:
  - The City College of New York
  - Medgar Evers College
  - LaGuardia Community College
  - Queensborough Community College
  - New York City College of Technology
- Rutgers University
- Stevens Institute of Technology
- New Jersey Institute of Technology
- Goddard Institute for Space Studies
- Southern Connecticut State University/Yale University
- State University of New York at Stony Brook

- We would welcome any other colleges in NY, NJ or CT willing to collaborate with our NYCRI

Other NYCRI Activities

- NASA's NYCRI supports all the high school students and teachers and related costs.
- All the undergraduate and graduate students are supported by the NSF Research Experiences for Undergraduates (REU); NASA CIPAIR; New Jersey Space Grant Consortium and GISS scientists or university professors, who are the recipients of NASA research awards.
- Presentations (each week @ research location, mid-semester @GISS, and final conference at @one of our participating colleges along with 400 other NASA, NSF, NOAA and DOD researchers)

- Learning units based on summer research are developed and implemented by the participating NYCRI high school teachers and college professors.

- All the final research power-point poster presentations (for the last 10 years) can be found on our NYCRI web-site http://education.gsfc.nasa.gov/nycri

- Some examples of the New Jersey research:

Autonomous Vehicle Control via Color Tracking and Ultrasonic Sensing

Abstract

Autonomously controlled vehicles utilize various sensors to survey their environment in order to operate independently of human interaction. Such vehicles can work in conjunction with one another to form a convoy with only one human controlled lead car. This technology could be integrated into various subdivisions, including military, commercial, and industrial sectors. In order to develop such technology, a mathematical model which defines the general motion of a vehicle must be constructed. Also, a set of control laws that guide the autonomous vehicle is needed. MATLAB was used to write a simulation program based on the model and control laws to test the autonomous vehicle's artificial intelligence before implementation onto a physical car. Standard radio controlled (RC) cars are used as the vehicles. The follower vehicles are equipped with Arduino microcontrollers, motor shields, CMUcam2 color tracking cameras, Parallax Ping))) ultrasonic sensors, and servos to carry out all necessary measurements and calculations. Using these components, the distance and offset angle to the vehicle ahead is found and converted to steering angle and motor speed outputs. The process of analyzing, processing, and executing repeats continuously, resulting in efficient function of the autonomous vehicle control systems.

Previous Problems

- Limited viewing angle of the camera
- Changes in lighting conditions altered color, impacting the distance measurement and making the camera lose track of the lead car
- Little flexibility due to preset values: color to detect, and fast/slow motor speeds

Goals

- ☑ Implement a control law which incorporates the rate of change of the distances between the cars for optimal function.
- ☑ Introduce a frontal servo for the CMUcam2 and Ping))) for 180° degree viewing.
- ☑ Utilize a variable steering and speed capable vehicle to lead the convoy for optimal following by the followers.

Sponsors:
National Aeronautics and Space Administration (NASA)
NASA Goddard Space Flight Center (GSFC)
NASA Goddard Institute for Space Studies (GISS)
NASA New York City Research Initiative (NYCRI)
New Jersey Space Grant Consortium (NJSGC)

Contributors:
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Kimberly Lam, High School Student

Special thanks to John Petrowski & Alexey Titovich of Rutgers University

Theory

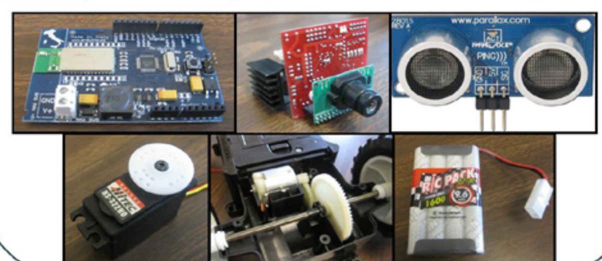
The vehicle control system requires a lead car and a follower car. Additional follower cars may be added to create a convoy. The lead car is a radio controlled (RC) car and the major vehicle that the autonomous follower cars pursue. Behind the lead car and subsequent followers is a colored cylindrical object. The follower car tracks the object within its range, processes sensor inputs, and programs outputs to follow as needed.

The algorithm of the microprocessor requires two basic functions: a setup and a loop. Within the setup function, the connected parts are initialized and prepared for performing their respective commands. The loop is essential for the following process. The sensors track the colored object and the car's distance, then the Aduino microcontroller relays the information to be implemented into the control laws, and outputs the necessary values to power the motor and servo to follow.

Parts

Clockwise from top-left

<u>*Arduino*</u>: Microprocessor where all the subsequent parts are connected to in order to bridge a universal communication between each other. All data is received, processed, and executed with the motor shield here.
<u>*CMUcam2*</u>: Color tracking camera which takes the pixels of a determined color and finds center of the color to understand steering angle needed.
<u>*Ping)))*</u>: Ultrasonic sensor which sends and receives ultrasonic waves to analyze distance between the two cars.
<u>*Servo*</u>: Connected to front wheels to turn car & another to turn sensors.
<u>*Motor*</u>: Built-in with RC car to allow for rear wheel drive.
<u>*9.6V Battery*</u>: Standard battery to power RC/autonomous vehicle system.

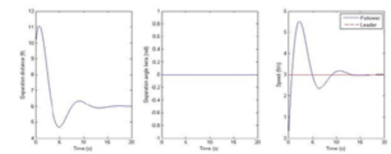


Troubleshooting

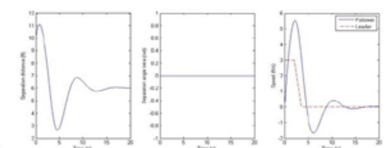
This project has been undertaken by groups prior in an attempt to create a fully functional convoy of autonomous vehicles. We reused many parts and found others to be dead or of no use to our current improvements. Much time was spent early on in the project in order to understand and utilize these parts for optimizing our current advancements. It was also during this time that we realized that the CMUcam2 was not a reliable source of distance measurement due to frequent light changes. We also fixed a problem in the code which caused the steering servo to twitch.

Simulation

In order to test our new control laws before constructing physical cars, a computer simulation was written in MATLAB. The simulation allowed the user to input the initial positions of the lead and follower vehicles, the desired separation distance, and several other constants. The user can then specify the path of the lead vehicle by defining the turning angle and speed as functions of time. The simulation then utilized our control laws to adjust the speed and turning angle of the follower and animated the result so we can see how the physical cars will behave. Below are some examples of graphs output by the simulation:



Separation distance, body angle, and speed as functions of time - lead vehicle driving at 3ft/s in a straight line



Lead vehicle driving at 3ft/s and braking to a stop

Initial condition setup for the simulation

Approach & Conclusion

With the addition of the ultrasonic Ping))) sensor and a swiveling frontal servo, a few changes to the design and the code were necessary for proper function. The ping pong ball that was originally on the cars ahead would now become a tall cylindrical object since distance measurement is now used with the ultrasonic sensor and not the camera. Not to mention, the swiveling frontal servo added a much greater viewing angle for the follower - 180° were added. This made the follower much more versatile and conquered the problem where the follower would suddenly lose the lead vehicle due to a sharp turn.

Future Goals

- Build this system on a larger scale.
- Implement multiple followers with the newer, more accurate technology and control laws to create a convoy.
- Test mobility on rugged terrain or with multiple obstacles.
- Implement GPS technology and wireless transmitters to achieve a more versatile system.

References

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Gartzman, Steve, Marifae Tibay, Thien Win, Steve Agudelo, Christian Cuentas, and Adekola Adesina. *A Convoy of Autonomous Vehicles*. Rutgers University, 24 Apr. 2009. Web.
Rowe, Anthony, Charles Rosenberg, and Illah Nourbakhsh. *CMUcam2 Vision Sensor: User Guide*. 2003. Print.
Titovich, Alexey. *Vehicle Automation via Light Sensing*. 2009.

UAV SYSTEMS FOR CIVILIAN APPLICATIONS

Abstract

Unmanned aerial vehicles (UAV) are the logical successors to modern aircraft and advancements in automated technology. The current generation of UAVs is focused on wartime capabilities and reconnaissance, leaving an existing market untapped by UAV technology: the commercial field. There are hundreds of applications for UAV technology in the civilian market, from emergency response applications and media outlets to communication technicians and horticulturalists.

However, a versatile UAV does not currently exist for civilian purposes. A UAV of this capability should be compact, lightweight, and have the ability to carry a multitude of interchangeable instruments to suit its application. The concepts of UAV technology combined with interchangeable parts can become a powerful tool for commercial applications and can shape the future of aviation.

History

- **U**nmanned **A**erial **V**ehicle- any aircraft which operates without a human pilot on board during flight.
- UAV technology originated in 1964 during the Vietnam War
- **The Defense Advanced Research Project Agency (DARPA)** is a federally funded program dedicated to sponsoring UAV development for military purposes.
- In recent years, UAV technology has been used throughout the government.
- UAV technology ranges in size from a mere six inches to nearly two hundred feet in wingspan.

Pros and Cons of Current UAV Technology

Advantages

- Can do jobs that are dirty, difficult, and dangerous
- Combat/Reconnaissance
- Less risk to humans
- More efficiency
- Can acquire otherwise unattainable information

Disadvantages

- Limited air time
- Shorter lifespan than manned combat aircraft

Civilian Applications

The UAV technology currently employed by the military can be applied to civilian life. Such applications include:

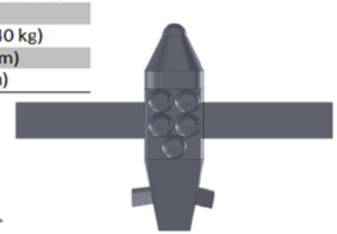
- National security
- Agriculture
- Police
- Fire services
- Commercial surveillance
- Aviation safety and security
- Private scientific research
- Media/entertainment purposes
- Power/gas line patrol

Our Design

Our design for a civilian UAV had to fit the following criteria and specifications:

- Medium-sized
- **Multi-purpose UAV** for commercial use
- **Interchangeable capsules** to house various technologies

Range	**900 mi (1 450 km)**
Cruising Speed	75 knots (140 kph)
Service Ceiling	20 000 ft (6 100 m)
Endurance	24 hours
Payload	750 lbs. (340 kg)
Wingspan	50 ft (15.4 m)
Length	25 ft (7.6 m)



Alternate Design Matrix

		Predator UAV		Propeller Engine		Solar/Electric Engine		Jet Engine	
Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Range	20%	10	2	8	1.6	8	1.6	8	1.6
Payload	25%	8	2	8	2	5	1.25	4	1
Cost	30%	3	0.9	6	1.8	2	0.6	2	0.6
Air time	15%	8	1.2	8	1.2	8	1.2	4	0.6
Speed	10%	6	0.6	9	0.9	2	0.2	5	0.5
Total	100%	35	6.7	39	7.5	25	4.85	23	4.3

Power Source

- Predator UAV- control
- **Propeller/ Piston Engine**- low speed, medium altitude, low maintenance, low rate of fuel consumption
- Solar-Powered Electric engines- extremely low speed (20 mph), high altitude, high maintenance, no fuel consumed
- Jet Engine- high speed, high altitude, high maintenance engine with a high rate of fuel consumption

Based on these characteristics, the best power source for our commercial UAV was the propeller-driven aircraft (see matrix above).

Guidance

- **Autonomously controlled unit**- requires pre-programmed software to plot the aircraft's course so it can follow a pre-determined path from take-off to landing.
- **Pilot-controlled unit**- manually operated using radio signals from a ground station, thereby increasing the reliability of the aircraft system.

Communications

- **Air-to-air communication**- radio transmissions between two aircraft to communicate relative positions and avoid collisions.
- **Air-to-ground communication**- radio and data transmission between the aircraft and ground control stations, including air traffic control.

These communication systems can plot navigation data and warn pilots and air traffic controllers of intersecting flight paths.

- NASA, in conjunction with the US Air Force, is currently developing **Automatic Collision Avoidance Technology (ACAT)** to prevent aircraft collisions in the air and on the ground.

This technology is currently too large and expensive for commercial use; however, it opens up possibilities for better aviation communication in the future.

Onboard Technologies

- Infrared camera
- Navigation camera
- GPS
- Synthetic radar
- Communications equipment

Sponsors:
National Aeronautics and Space Administration (NASA)
NASA Goddard Space Flight Center (GSFC)
NASA Goddard Institute for Space Studies (GISS)
NASA New York City Research Initiative (NYCRI)
Stevens Institute of Technology (SIT)

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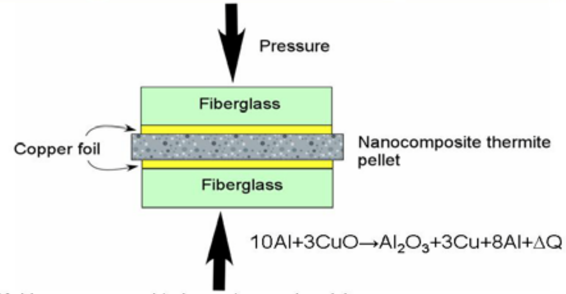
STEVENS Institute of Technology

Use of Nanotechnology to Investigate Bonding Strengths in Thermite Welding



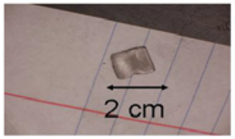
$$10Al+3CuO \rightarrow Al_2O_3+3Cu+8Al+\Delta Q$$

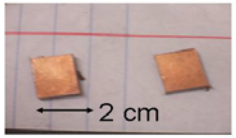
RATIONALE:

To find the optimal composition and density for nanocomposite welding.

Compare bonding strengths in different stoichiometrically determined (composites) pellets of Aluminum and Copper Oxide(CuO).

Attempt thermite welding two, copper-foil covered, fiberglass plates using 8Al-3CuO, 10Al-3CuO, 12Al-3CuO



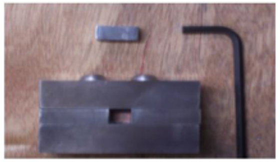


APPLICATIONS:

Composition & manufacturing of microchips
Welding in oxygen free environments (Space & Ocean)
and more adhesion for joining

PROCEDURE:

1) Place measured amount of powder (Al-CuO of mole of choice) in a 3 piece mold (approximately 9mm x 8 mm).



2) Place die on top of powder
3) Compress the die upon the "powder" to desired MPa reading (either 10 MPa's or 20 Pa's)

Data: (Only shows 10 Mol because proved to have stronger bonds)

10Al-3CuO (10 MPa's)

Sample	Mass as Powder	MPa's (pressure)	Mass as Pellet	Thickness (mm)
1	.05	10	.03	.35
2	.14	10	.10	.80
3	.15	10	.12	.77
4	.21	10	.17	.98
5	.10	10	.08	.63
6	.20	10	.19	1.22
7	.09	10	.07	.66
8	.07	10	.06	.51
9	.16	10	.15	.84
10	.06	10	.04	.38

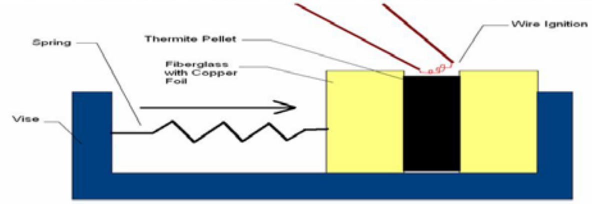
10Al-3CuO (20 MPa's)

Sample	Mass as Powder	MPa's	Mass as Pellet	Thickness
1	.05	20	.04	.44
2	.14	20	.11	.66
3	.15	20	.15	.77
4	.21	20	.17	.89
5	.10	20		
6	.20	20	.18	1.05
7	.09	20	.04	.32
8	.07	20	.06	.47
9	.16	20	.14	.73
10	.06	20	.05	.37

* 10Al-3CuO (20 MPa's) would only ignite under 60 volts of amperage unlike the 8 Mol and 10 Mol under 30 volts

** After sample 2 (10 Al-3Cuo (20 MPa's)), the pellets were compressed between the plates in the mold creating much more flattened pellets to produce a sure thickness reading.

4) The "powder" is now a pellet. Take apart mold by unscrewing the 3 pieces and carefully remove pellet (very fragile) from mold
5) Measure thickness, using a digital caliper.
6) Measure mass again to note change in mass?
7) Sandwich pellet between 2 copper foil covered, fiberglass plates.
8) A small spring is placed on one side of vise pushing against sandwich.

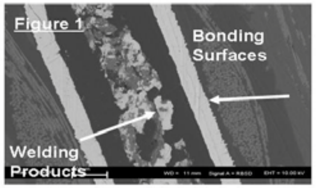


9) Ignition is achieved using a tungsten wire, braided with a 30 Volt electric potential.
10) Place wire in contact with top part of pellet (should be slightly sticking out of sandwich).
11) Plug in cord, and press ignition button.
12) Check weld strength under SEM or by gentle prying with one's finger tips.

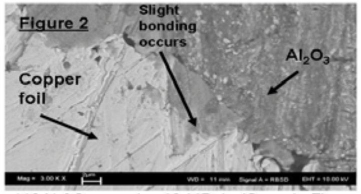
RESULTS:

8 Mol composite gave poor adhesion
12 Mol was difficult to ignite
10 Mol optimal adhesion when 60 volt applied to pellet between scratched copper coated pads
There was evidence of molten products i.e., alumina and CuAl alloy.
Future Work: Focus on incorporating the alloy into the foil to create bonded interface.

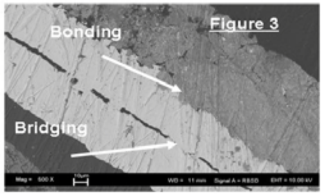
SEM Images: (Selected few cross-sectioned bonds between pellet and plates.)



Indicates bonding surfaces of copper foil and initial welding products i.e., alloys probably including $CuAl_2$.



*10Al-3Cuo under 10 MPa's (Sample 7) Pellet was .07 grams with a thickness of .66 mm. Image indicates bonding between foil and Aluminum-oxide.



*This image indicates bridging and bonding & needs further investigation.

Scanning Electron Microscope

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Questions?