2011 Annual Report

UAV Research at CSOIS, Utah State University

by
YangQuan Chen, Director,
Center for Self-Organizing and Intelligent Systems (CSOIS)
http://www.engr.usu.edu/wiki/index.php/OSAM_UAV
http://mechatronics.ece.usu.edu/yqchen/
(Contact: yqchen@ieee.org) Last updated: 4/15/2012

Contents:

1. Funding Awarded

2011 is a good year for CSOIS's external funding. We were awarded the following

1.1 $50K. NSF RAPID (2011-2012) **"Low Cost Personal Remote Sensing for Cognitive Disaster Assessment with Enhanced Human-Machine Interface" Award# NSF-IIS 1138632**

Abstract: The project studies the use of advanced Human-Machine Interface kits such as helmet displays and Virtual Reality goggles with low-cost autonomous Umanned Aerial Vehicles (UAV) and assesses their impact on the ground operator's cognitive load, and explores the addition of the capability to enable the UAV with a certain amount of cognitive ability so that it can suggest places in the scene to make observations.

This project impacts search and rescue, disaster mitigation, mapping and assessment, and broadens the perspectives of faculty and students through an international collaborative effort.

1.2 $300K. NASA UAS2NAS (2011-2014) - Grant Number NNX11AO77A

Project Title: **Cognitive autopilot techniques and flight evaluation for integrating low cost personal remote sensing UAVs in the national airspace system**

Background: *Recently, there has been a rapidly increasing interest in small unmanned aerial vehicles (UAVs). With the emergence of high power density batteries, long range and low-power micro radio devices, cheap airframes, and powerful micro-processors and motors, small/micro UAVs have become applicable in civilian circumstances like remote sensing, mapping, traffic monitoring, search and rescue, etc. Using multi-UAV based remote sensing platform to achieve multi-spectrum images with high temporal and spatial resolutions is now possible based on COTS modules. Using an analogy to "personal computer" in the 1950s, we are now at the era of "personal remote sensing." How to integrate these low cost "personal remote sensing" UAS into the national air space systems (NAS) calls for focused efforts in various aspects.*

Key objectives: *Focusing on small personal remote sensing UAS platform matured at the PI's center with two successfully approved FAA CoAs, we propose to assess, evaluate and report on UAS autopilot test technologies for robotic CONOPS that include decision making strategiesfor nominal and off nominal operations under both single and multi-UAV settings.*

Proposed methods/techniques: *Based on our award-winning UAS platforms and extensive experience on autopilots and IMUs, we propose to quantify the capabilities and reliabilities of the autopilots/IMUs in the framework of "cognitive UAS flight." That is, on top of autopilot, a cognitive layer is added to monitor, quantify and adapt the autopilot for more reliable flight under various off normal situations such as link loss, GPS anomaly, gusts etc. These off-normal scenarios will be formalized into flight tests or pre-flight simulation on GCS (ground control system) for quantification for specific UAS type/size. Then, cognitive safe-flight procedures will be summarized and suggested to FAA for SFAR development. Specifically, we propose to investigate ADS-B's potential integration in single and multiple UAV in our chosen open-source Paparazzi Autopilot to make autopilot "cognitive". We will also look into the benefits from 1) using forward-looking video camera for airworthiness enhancement, 2) novel HMI interface and joystick-via-datalink, and 3) interoperability based on the frameworks of JAUS and STANAG-4586 for "autopilot virtualization."*

Significance of the proposed work: *Integrating small low cost UAS as a personal remote sensing system into NAS has a significant implication to future UAS commercial flight and new services enabled. The proposed work paves the path towards regular regulated small UAS flights for personal remote sensing missions, which aligns well to the objectives of the solicitation and to NASA interests and programs in general.*

We continue to have UWRL MLF support in 2011-2012 financial year for three projects:

- Utah Water Research Laboratory (UWRL) MLF Seed Grant: "**Ultra light, High Grain UAV Fish Tracking Antennas**" (year-2) $37,085
- Utah Water Research Laboratory (UWRL) MLF Seed Grant: "**Low Cost Vertical Take Off and Landing Personal Remote Sensing Systems for Water Engineering: AggieVTOL**" (year-2) $49,154
- Utah Water Research Laboratory (UWRL) MLF Seed Grant: "**Multispectral UAV Collaborative Remote Sensing System for Irrigation Water Management and Ecological Assessment**" (year-5) $79,963

2. Funding Proposals

In 2011, we had some UAV-related declined funding proposal efforts. We briefly document them as follows:

- NSF CPS – "Optimal Cyber-Physical Measurement and Control of Spread of Phragmites Australis" $**1,464,225**
- NSF DNDO - ARI-MA: Cognitive self-disposable UAV swarm mapping of nuclear pollution. $**1,591,891**
- We also tried to team for NSF SEP (Logan Lagoon – not fully started, will try later)
- (pending) ARL DURIP. $100,000.00 "**Towards A Low-Cost UAV-Based Collaborative Multi-Spectral Personal Remote Sensing System: From RBG+NIR to TIR and SWIR Bands**"

3. Service

- In 2011, Dr. Chen was named as TC Chair for the Technical Committee of "Aerial Robotics and Unmanned Aerial Vehicles" for IEEE RAS (Robotics and Automation Society) for the term 2012-2015. Web: http://www.flyingrobots.org/ or http://tab.ieee-ras.org/committeeinfo.php?tcid=1
- Dr. Chen co-organized the ASME DED MESA TC symposium on SUAVTA (Small UAV Technologies and Applications" hold in Washington DC in August 2011. It is in its third time "**The Third Symposium on Small Unmanned Aerial Vehicle Technologies and Applications (SUAVTA¡'11)" Papers are put here: http://mechatronics.ece.usu.edu/uav+water/MESA11-SUAVTA/**
- Dr. Chen served as Advisory Committee for ICUAS2011 in Denver. http://uasconferences.com/ and he was named Workshop Chair for ICUAS2012.
- We offered a full day workshop at ICUAS11 on May 24, 2011 on "Multi-UAV based multi-spectrum collaborative personal remote sensing - concept, platform, and applications". Around 20 participants attended.
- Dr. Chen was invited to serve on the editorial board of "International Journal of Advanced Robotic Systems" as AE (Associate Editor). http://www.intechopen.com/journals/show/international_journal_of_advanced_robotic_systems/editorial-board
- Mentored USU URCO project of Christopher Michael Coffin. "Prognostic Health Management System for Improving Airworthiness for Personal Remote Sensing UAVs" 2011

- Hosted UAV researchers from Germany for 6 months stay each. Tobias Fromm, Johannes Kaplanek
- Hosted AUVSI Mountain West Chapter Meeting June 2011 at CSOIS.
- Hosted visits from other community visitors;
- Dr. Chen was named Vice President of NTUAA US West (Nanyang Tech Univ Alumni Association USA West)

4. Honors and Distinctions

- We won AUVSI SUAS 2011 First Place Overall again in summer 2011. Story at http://www.usu.edu/ust/index.cfm?article=50035 and http://www.auvsi.org/news/#SUAS2011
- "UAV remote sensing" we are among top 10 in the world in ScienceDirect.com
- We offered a full day workshop at ICUAS11 on May 24, 2011 on "Multi-UAV based multi-spectrum collaborative personal remote sensing - concept, platform, and applications". Around 20 participants attended.
- Calvin Coopmans was featured at USM (Unmanned Systems Magazine) Issue 10/10. Page-43, as in column "Ones to watch"
- USM (AUVSI Unmanned Systems Magazine) 2011 issue 11 page-13, "UAS2NAS" funded project information – USU is part of it among some big players.
- Dr. Chen was invited to give a seminar at "*Center for Self-Organizing and Intelligent Systems (CSOIS) and Autonomous Ground Vehicle Research Programs*" http://www.csir.co.za/ The Council for Scientific and Industrial Research (CSIR) in South Africa. March 2011. Pretoria, South Africa.

5. Publications

- **Theses**
  - 2011. Dee Long Di. "**Cognitive Formation Flight in Multi-Unmanned Aerial Vehicle-Based Personal Remote Sensing Systems**." Master of Science Thesis. http://digitalcommons.usu.edu/etd/985/
  - 2011. Tobias Fromm. "**Visual Flight Support for Low-Cost Personal Remote Sensing Systems**" Master Thesis in Computer Science, Hochschule Ravensburg-Weingarten. Thesis done at CSOIS USU under supervision of Dr. Chen. (09/10-02/11)
- **Books/Monographs**
  - Ying Luo+ and YangQuan Chen*. "**Fractional Order Motion Controls**" John-Wiley and Sons, Inc., 2012 (Under initial copyediting, to appear summer 2012, 410 pages)
  - Haiyang Chao+ and YangQuan Chen*. "**Remote Sensing and Actuation Using Unmanned Autonomous Vehicles**" John-Wiley and Sons, Inc., 2012 (Final copyediting, to appear summer 2012, 210 pages) http://www.wiley.com/WileyCDA/WileyTitle/productCd-1118122763,subjectCd-EE79.html
  - Christophe Tricaud+ and YangQuan Chen*. "Optimal Mobile Sensing and Actuation Policies in Cyber-physical Systems". Springer. ISBN 978-1-4471-2261-6. 2012. (170 pages) http://www.springer.com/engineering/robotics/book/978-1-4471-2261-6

- Brandon Stark, YangQuan Chen and Mac KcKee (2012). "AggieVTOL: A Vertical Take Off and Landing Unmanned Aerial Vehicle Platform for Personal Remote Sensing". IGI Global Press. A chapter in "Prototyping of Robotic Systems: Applications of Design and Implementation." Editors: Dr. Tarek Sobh & Dr. Xingguo Xiong, Univ. of Bridgeport, Connecticut, USA, 2012. 35 pages. http://www.igi-global.com/book/prototyping-robotic-systems/58292

- **Journal Papers (accepted/published, + student author, * corresponding author)**
  - Long Di+, Tobias Fromm+, and YangQuan Chen*. "A Data Fusion System for Attitude Estimation of Low-cost Miniature UAVs." **Journal of Intelligent and Robotic Systems.** 2011. DOI: 10.1007/s10846-011-9569-1
  - Ying Luo*, Haiyang Chao+, Di Long+ and YangQuan Chen. "Lateral Channel Fractional Order [PI]^\alpha Control of A Small Flying-Wing UAV: Controller Design and Flight Tests." **IET Control Theory and Applications.** (accepted on 6/2/2011) doi: 10.1049/iet-cta.2010.0314

- **Conference papers (accepted/published, + student author, * corresponding author)**
  - Tobias Fromm+, Long Di+, YangQuan Chen* and Holger Voos. *Visual Attitude Estimation For Low-Cost Personal Remote Sensing Systems*. **Third International Workshop on Small UAV Technologies and Applications (SUAVTA), 7th ASME/IEEE International Conference on Mechatronics and Embedded Systems and Applications (MESA11), part of the 2011 ASME DETC/CIE.** https://www.asmeconferences.org/IDETC2011/
  - Yaojin Xu+, Di Long+ and YangQuan Chen*. *Consensus Based Multiple Small Fixed-Wing UAV Formation*. Ibid.
  - Di Long+, Haiyang Chao+, Jinlu Han+ and YangQuan Chen*. *Cognitive Multi-UAV Formation Flight: Principle, Low-Cost UAV Testbed, Controller Tuning And Experiments.* Ibid.
  - Di Long+ and YangQuan Chen*. *Autonomous Flying Under 500 USD Based on RC Aircraft*. Ibid.
  - Calvin Coopmans+, Di Long+, Austin Jensen+, Aaron Dennis+, and YangQuan Chen*. *Improved Architecture Designs For A Low Cost Personal Remote Sensing Platform: Flight Control And Safety.* Ibid.
  - Pooja Kavathekar+ and YangQuan Chen*. Vehicle Platooning: A Brief Survey and Categorization. ibid
  - Long Di+, Tobias Fromm+, and YangQuan Chen*. *A Data Fusion System for Attitude Estimation of Low-cost Miniature UAVs.* **Proc. of the 2011 International Conference on Unmanned Aerial Systems (ICUAS 2011), Denver, CO. May 2011**
  - Jensen, A.M.+*, Hardy, T., Mckee, M. & Chen, Y.Q. *Using a Multispectral Autonomous Unmanned Aerial Remote Sensing Platform (AggieAir) for Riparian and Wetland Applications.* **2011 Proc. IEEE Int. Geoscience and Remote Sensing Symp. (IGARSS11)**
  - Hadi Malek+, Ying Luo+, and YangQuan Chen*. *Tuning Fractional Order Proportional Integral Controllers for Time Delayed Systems With a Fractional Pole* DETC2011-

47872 **Proc. of the ASME DETC/CIE 2011 Conferences, Washington DC, August 29-31, 2011. The Fifth International Symposium on Fractional Derivatives and Their Applications, part of The 7th ASME/IEEE MESA (Mechatronics and Embedded Systems and Applications) Conference.**

- Dali Chen, YangQuan Chen*, and Dingyu Xue. Digital Fractional Order Savitzky-Golay Differentiator and its Application, DETC2011-47864 ibid
- Xiaona Song+*; Tejado, I.+; YangQuan Chen; Stabilization for fractional-order networked control systems with input time-varying delays **Advanced Mechatronic Systems (ICAMechS), 2011 International Conference on** Publication Year: 2011 , Page(s): 39 - 42
- Hyo-Sung Ahn*; YangQuan Chen; Moore, K.L.; Multi-agent coordination by iterative learning control: Centralized and decentralized strategies **Intelligent Control (ISIC), 2011 IEEE International Symposium on** Digital Object Identifier: 10.1109/ISIC.2011.6045400 Publication Year: 2011 , Page(s): 394 - 399
- Xiaona Song+; Tejado, I.+; YangQuan Chen*; Remote output feedback stabilization for fractional-order systems via communication networks; **Resilient Control Systems (ISRCS), 2011 4th International Symposium on** Digital Object Identifier: 10.1109/ISRCS.2011.6016088 Publication Year: 2011 , Page(s): 49 - 54
- Tejado, Inés+; Vinagre, B. M.*; Chen, YangQuan. Fractional Gain Scheduled Controller for a Networked Smart Wheel: Experimental Results. **Proc. of the 2011 IFAC World Congress,** Volume # 18 | Part# 1, Milano, Italy. 10.3182/20110828-6-IT-1002.01094

6. Ph.D. students (Annual Progress Reports and 2012-2013 Research Plans)

- Calvin Coopmans (passed Ph.D. Comprehensive Exams in Feb. 2012)
- Brandon Stark
- Jinlu Han (passed Ph.D. Comprehensive Exams in Feb. 2011)
- Austin Jensen (AAFC Manager http://aggieair.usu.edu)

Austin Jensen (2011 Annual Summary and Vsion for 2012-2013)

Media coverage:

- http://www.futureoftech.msnbc.msn.com/technology/technolog/slingshot-drone-blast-big-kids-715180
- http://www.suasnews.com/2012/04/14577/the-aggie-air-flying-circus/
- http://diydrones.com/profiles/blogs/announcing-t-3-round-3-the-reliability-round
- http://battleland.blogs.time.com/2012/04/11/the-drones-are-coming-oops-theyre-already-overhead/#ixzz1rkJeYLIK
- http://www.fastcompany.com/1830538/aggieair-flying-circus-utah-state-university

AUVSI

ASSOCIATION FOR UNMANNED
VEHICLE SYSTEMS INTERNATIONAL

9th Annual

STUDENT UAS COMPETITION

FIRST PLACE

2011

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STUDENT UAS COMPETITION

BEST ORAL BRIEF

2011

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9th Annual

STUDENT UAS COMPETITION

BEST JOURNAL PAPER

2011

AUVSI

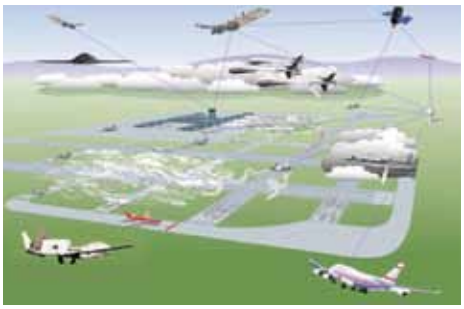
ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL

9th Annual

STUDENT UAS COMPETITION

BEST FLIGHT

2011



NASA's illustration of how UAS in the NAS will eventually work. Image courtesy Dryden Flight Research Center.

NASA Awards Contracts for UAS in the NAS Research

NASA's Dryden Flight Research Center has awarded contracts to six companies to assist the Unmanned Aircraft Systems Integration in the National Airspace System project, as well as four other cooperative agreements to universities for similar work.

The goal of the UAS in the NAS project, as its name suggests, is to reduce the technical barriers related to safely flying unmanned aircraft in public airspace. The combined value of the awards comes to just under $12.6 million, according to NASA.

The contracts went to LE Tech of Santa Fe for developing a portfolio analysis tool, $3 million; Sensis Corp. of Campbell, Calif., for systems analysis of UAS integration in the NAS, $2.8 million, and another $368,000 for UAS analysis and simulation; Intelligent Automation of Rockville, Md., for modeling and simulation, $2.5 million; Boeing, of Huntington Beach, Calif., for modeling and simulation, $1 million; Honeywell International of Albuquerque, for separation assurance and sense and avoid, $943,000; Modern Technology Solutions of Alexandria, Va., for alternative classification schemes, $341,000.

The cooperative agreements went to the University of Michigan, $246,000, and Embry-Riddle Aeronautical University, $731,000, to define a UAS classification scheme and approach to determining FAA regulation airworthiness requirements applicable to all UAS digital avionics; Utah State University, $300,000, and New Mexico State University, $344,000, to integrate and test mature concepts for technical elements and evaluate the performance of technology development, including full-mission simulations and flight tests.

Oshkosh Defense's TerraMax vehicle. Photo courtesy Oshkosh Defense.

Oshkosh, Marine Lab Prove Convoy Mission Scenario

Oshkosh Defense and the U.S. Marine Corps Warfighting Lab recently completed the second testing phase of a project that aims to assess the capability of the company's TerraMax unmanned vehicle in a convoy scenario.

The limited technical assessment, held from 22-28 Aug. at Camp Lejeune, N.C., trained six Marines on different convoy scenarios involving the TerraMax and the company's Operator Control Unit.

The test rotated the Marines through different positions in the convoy, including inside the command and control vehicle or riding along in the autonomous vehicle, and played out different and increasingly complex mission scenarios. The testing was assessed by the Marine Corps War Fighting Lab and the Naval Surface Warfare Center Dahlgren. The warfighting lab partnered with the Joint Ground Robotics Enterprise for the testing, which put out a request for project proposals through the Robotics Technology Consortium, where there was a competitive selection process for the company involved in the exercise.

The convoys operated in various situations, including with the unmanned vehicle in the lead, with five vehicles total.

"We got a lot of great feedback in the exercises with the LTA," says John Beck, chief unmanned systems engineer for Oshkosh. "One of the things the field test bench were pushing for was asking the Marines how they would actually use the system in theater, so it was really focused on the concept of operations and the tactics, techniques and procedures for integrating this unmanned system in to manned operations in theater."

Now with two rounds of testing completed — the first back in May at Fort Pickett, Va., — Oshkosh is now taking that feedback and prioritizing what should be implemented over the next 12 months. The addition of another autonomous truck to the convoy is one of the possibilities.

"The emphasis of this experiment was really to … test the ability of Marines to be trained and use the system as well as sort of get their feedback again for how this technology could be deployed," says Beck.

The warfighting lab's goal with the project is to develop the concept of operations and create procedures around the scenario and refine system requirements. Oshkosh is looking at another technical assessment in mid 2012 and then a limited objective experiment, where they turn the system over to Marines in a larger exercise, probably around August 2012 at Camp Lejuene, N.C.

Cargo UAS Comes Closer with new Afghanistan Deployment

U.S. Naval Air Systems Command says it will deploy the service's first unmanned cargo aircraft to Afghanistan next month.

Two Lockheed Martin/Kaman K-Max unmanned helicopters will undergo a six-month deployment to augment U.S. Marine Corps ground and air logistics operations, says Rear Adm. Bill Shannon, program executive officer for Unmanned Aviation and Strike Weapons.

The move comes after a successful quick reaction assessment in Yuma, Ariz., in August. Marine Unmanned Aerial Vehicle Squadron 1 conducted the assessment, which accurately replicated a week of operations in Afghanistan, complete with high temperatures and elevated terrain. The K-Max carried a total of 33,400 pounds of cargo during the assessment.

Boeing had been competing against the K-Max with its A160T Hummingbird, but a quick reaction assessment of that vehicle has not been carried out and it won't be deployed to Afghanistan.

gest challenges facing this industry, a challenge shared among others, is the interdisciplinary training of engineers. The next wave of unmanned systems will require a breadth of technologies that will bridge together in novel ways. The intimate bridging of these technologies will call for engineers to branch out of their fields more so than we have seen in the past.

Cal Coopmans

Born: Montana, 1981

Academic Status: Just began his Ph.D in electrical engineering, which he hopes finish in four years. After that, he might stay in academia because of his love of research, but he's not sure he'll be a professor.

How He Got Interested in Unmanned Systems: I've always been fascinated by robots — when I was young I used to have my mother take me to the library so I could pour over books filled with pictures of artificial hands and other mechanisms. As an undergraduate I worked in a student satellite lab, so it's been a small step to unmanned systems.

What He learned From the Competition: That hard work and preparedness do pay off. Also that AUVSI volunteers are some of the best people in the industry: It was a fantastic, rewarding experience.

Advice for Up and Coming Students: Study hard, but keep your mind open. The best contributions are often inspired by obtuse facts and unrelated problems.

What He'd Like to Do: I think we're at an interesting time for unmanned systems. I am doing my work on a concept called "Personal Remote Sensing," or PRS. Much like the beginning of the personal computer revolution, right now it's hard to imagine the utility of having remote sensing systems in homes or small businesses (such as UAVs for automatic land surveying), but eventually personal remote sensing will evolve beyond toys like the AR.Drone. With levels of autonomy, new doors will open.

Cal Coopmans, third from left, and his team from Utah State University at this year's Student Unmanned Air System Competition.

The Biggest Challenge He Sees Facing the Industry: The next real challenge is the mixing of legal policy creation and engineering innovation. For unmanned systems to be widely useable they must be functional of course, but also safe and predictable. Lawmakers and policy organizations such as the FAA will be instrumental in allowing engineers to create useful autonomous systems that are widely available and helpful to many people.

ICUAS'11 TUTORIAL
Tuesday, May 24, 2011

9:00 AM – 5:00 PM

MULTI-UAV BASED MULTI-SPECTRUM COLLABORATIVE PERSONAL REMOTE SENSING: CONCEPTS, PLATFORM & APPLICATIONS

Lecturers
YangQuan Chen
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TUTORIAL SUMMARY

There has been a rapidly increasing interest in small unmanned aerial vehicles (UAVs) over the recent years. With the emergence of high power density batteries, long range and low-power micro radio devices, cheap airframes, and powerful micro-processors and motors, small/micro UAVs may be used for civilian applications like remote sensing, mapping, traffic monitoring, search and rescue, etc.

Many applications and research projects could greatly benefit from acquiring remote sensing (RS) data with high temporal and spatial resolution. However, most of the available RS data is expensive, with low spatial resolution and single feature, sampled at a low frequency, and/or requiring long turnover time.

The proposed tutorial will present the development of a multi-UAV based remote sensing platform to achieve multi-spectrum images with high temporal and spatial resolution. It will include the concept of personal remote sensing, CSOIS UAV research focus, low-cost UAV platform developments for fixed-wing and VTOL aircrafts, the whole system architecture, practical applications, etc.

The AggieAir platform, which will be discussed in the Tutorial, is built entirely using off-the-shelf components/material. A remote control (RC) aircraft with cameras and other sensors is used to acquire the data. For more accurate navigation and aerial coverage, the RC aircraft is fitted with an autopilot. The autopilot (autonomously) flies the plane according to a given flight plan enabling the user to fly over an area of interest at any desired altitude without human intervention.

Different types of imaging sensors (cameras) will be discussed and illustrated. Some cameras have low resolution and data can be processed in real-time as the plane flies. Other cameras have a much higher resolution, but data must be processed after the plane has landed. All cameras cover the visual and the NIR bands of the spectrum and are easily accessible and available commercially.

The participants will be able to understand the concepts and broad applications and they will even be able to develop their *own* low-cost UAV platform based on the presented information.

INTENDED AUDIENCE

- Graduate students, scientists, engineers, UAV practitioners, researchers and developers, managers and other professionals.

TUTORIAL OUTLINE

- **Module1: Introduction to UAV**
- **Module2: UAV Flight Dynamics**
- **Module3: UAV Components**
- **Module4: UAV Applications**
- **Module5: UAV Projects in CSOIS**
- **Module6: UAV flight test**
- **Module7: AUVSI Student UAS Competition**
- **Module8: Airworthiness: FAA Standards**
- **Module9: UAV Research - General Pictures**
- **Module10: UAV Research - Visions and Efforts at CSOIS**

All tutorial materials will be delivered via Dropbox invitation.

BRIEF BIOGRAPHY OF PRESENTERS

YangQuan Chen received the B.S. degree in industrial automation from the University of Science and Technology of Beijing, Beijing, China, in 1985, the M.S. degree in

automatic control from the Beijing Institute of Technology, Beijing, in 1989, and the PhD degree in advanced control and instrumentation from the Nanyang Technological University, Singapore, Singapore, in 1998. He is currently an Associate Professor of electrical engineering at Utah State University, Logan, and the Director of the Center for Self-Organizing and Intelligent Systems.

His web page is at: http://mechatronics.ece.usu.edu/yqchen/

Austin Jensen is currently working at The Utah Water Research Laboratory (UWRL) as a research engineer while finishing his PhD degree at Utah State University. Before working with the UWRL, Austin worked at the Center for Self-Organizing and Intelligent Systems (CSOIS) as a research assistant where he has played a major part in creating the unmanned aerial vehicle (UAV) program at Utah State and in developing a low-cost autonomous UAV remote sensing platform from scratch. The team he supervised at CSOIS, as a graduate advisor, took second place at the AUVSI SUAS UAV competition. To meet an increasing demand for this platform, Austin has created a service center at the UWRL, which regularly flies the UAVs to obtain remote sensing data.

His web page is at: http://aggieair.usu.edu

(Dee) Long Di is a graduate research assistant at Center for Self-Organizing and Intelligent Systems (CSOIS) under supervisions of Dr. YangQuan Chen. He received his bachelor's degree in electrical engineering from Utah State University in 2009 and right now he is working on his master's degree focusing on multi-UAV cooperative flight control and low-cost UAV testbed development.

His web page is at: http://sites.google.com/site/deelongdi/

A Tutorial Proposal Submitted to
ICUAS 2012 (http://www.uasconferences.com)
(4-8 hours)

Full Title:
Low-cost UAV-based precision thermal infrared (TIR) mapping - A new Personal Remote Sensing capability: UAV platform, TIR payload, in-flight calibration and applications.

Short Title:
UAV-based TIR Personal Remote Sensing

Web: http://www.engr.usu.edu/wiki/index.php/OSAM
http://mechatronics.ece.usu.edu/uav+water/

Instructors

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Brief biographies of instructors:

YangQuan Chen received the B.S. degree in industrial automation from the University of Science and Technology of Beijing, Beijing, China, in 1985, the M.S. degree in automatic control from the Beijing Institute of Technology, Beijing, in 1989, and the Ph.D. degree in advanced control and instrumentation from the Nanyang Technological University, Singapore, Singapore, in 1998. He is currently an Associate Professor of electrical engineering at Utah State University, Logan, and the Director of the Center for Self-Organizing and Intelligent Systems. His web page is at: http://mechatronics.ece.usu.edu/yqchen/

Austin Jensen is currently working at The Utah Water Research Laboratory (UWRL) as a research engineer while finishing his Ph.D. degree at Utah State University. Before working with the UWRL, Austin worked at the Center for Self-Organizing and Intelligent Systems (CSOIS) as a research assistant where he has played a major part in creating the unmanned aerial vehicle (UAV) program at Utah State and in developing a low-cost autonomous UAV remote sensing platform from scratch. The team he supervised at CSOIS, as a graduate advisor, took second place at the AUVSI SUAS UAV competition. To meet an increasing demand for this platform, Austin has created a service center at the UWRL, which regularly flies the UAVs to obtain remote sensing data.

Calvin Coopmans is a graduate research assistant at Center for Self-Organizing and Intelligent Systems (CSOIS) under supervision of Dr. YangQuan Chen. He received his bachelor's degree in computer engineering from Montana State University in 2004 with minors in Mathematics and Computer Science. He holds a Master of Science degree from Utah State University (2010), focused on UAV-based personal remote sensing systems with thesis title "Architecture, Inertial Navigation, and Payload Designs for Low-Cost Unmanned Aerial Vehicle-Based Personal Remote Sensing." Currently, his Ph.D. work focuses on new and novel UAV PRS system implementations, payload development, and payload management; multi-IMU airworthiness and cyber-physical systems enabled by UAV-based PRS systems. He has participated and excelled in several student competitions including multiple Microsoft Imagine Cups, and Association for Unmanned Systems, International Student Unmanned Aerial Systems competitions.

Gary Strahan has been involved in infrared thermography for over 30 years. He has been an Infrared Thermography instructor for over 25 years. His wide range of experience with multiple infrared applications allows him to teach from direct experience. As president of Infrared Cameras Inc., Gary Strahan has experience with all aspects of infrared thermography, from the designing and manufacturing of infrared cameras to their many applications. Gary Strahan is a level III ASNT Thermographer.

Brief statement of the tutorial goals:

Recently, there has been a rapidly increasing interest in small unmanned aerial vehicles (UAVs). With the emergence of high power density batteries, long range and low-power micro radio devices, cheap airframes, and powerful micro-processors and motors, small/micro UAVs have become applicable in civilian circumstances like remote sensing, mapping, traffic monitoring, search and rescue, etc. Many applications and research projects could greatly benefit from having remote sensing (RS) data with high temporal and spatial resolutions. However, most of the available RS data is expensive, has low spatial resolution and single feature, is sampled at a low frequency, and/or has a long turnover time.

In our ICUAS2011 full day tutorial, we showed our participants how we developed our multi-UAV based remote sensing platform to achieve multi-spectrum images with high temporal and spatial resolutions. It includes the concept of personal remote sensing, CSOIS UAV research focus, low-cost UAV platform developments for fixed-wing and VTOL aircrafts, the whole system architecture, practical applications, etc.

In this ICUAS2012 tutorial, we will focus on TIR (thermal infrared) personal remote sensing (PRS) using small low cost UAVs. Recently, we have acquired exciting capability on TIR payload suitable for our small UAV platform. It is uncooled yet can achieve calibrated high precision temperature mapping. The TIR camera has resolution of 640x480 with Linux interface. High-Definition (HD) TIR is being worked out. In brief, we can now perform UAV-based scientific thermal measurement instead of simple thermal signature surveillance. This will open a huge possibilities for real world use of UAV-based PRS.

There will be enough details in the proposed tutorial that the participants should be able to understand the concepts, be impressed by the broad applications and even develop their *own* low-cost UAV platform having TIR capabilities based on the information we presented.

Description of the intended audience

- Graduate students in electrical engineering, mechanical & aerospace engineering, mechatronics, UAV practitioners, researchers and developers.

- Natural resource managers, water engineering professionals,
- Precision agriculture professionals
- Remote sensing professionals
- Environmental quality professional; Ecological field researchers

Tutorial outline (can be customized to 4 hours or 8 hours)

1. Introduction to UAV-based Personal Remote Sensing (PRS): concepts, history, motivations, goals (Dr. Chen)
2. Cyber-physical systems enabled by UAV-based PRS (Dr. Chen/Coopmans)
3. AggieAir UAV platform and sample applications (electronic systems, payload design, fail-safe features, and flight test protocol) (Austin Jensen)
4. Physics of TIR remote sensing for temperature mapping (Gary Strahan)
5. TIR payload development: integration and payload management architecture (Cal Coopmans)
6. Application scenarios (examples and participant mind storming session) (All: moderated by Austin Jensen)

Tutorial Materials:

To be delivered to participants via Dropbox invitation.

Tutorial References:

White paper (free access):

"*AggieAir: Towards Low-cost Cooperative Multispectral Remote Sensing Using Small Unmanned Aircraft Systems,*" Haiyang Chao, Austin Jensen, Yiding Han, YangQuan Chen, and Mac McKee, Advances in Geoscience and Remote Sensing, Gary Jedlovec, Ed. Vukovar, Croatia: ISBN: 978-953-307-005-6, IN-TECH, pp. 463-490, 2009.

Pdf link http://www.intechopen.com/articles/show/title/aggieair-towards-low-cost-cooperative-multispectral-remote-sensing-using-small-unmanned-aircraft-sys

Monograph (to appear in late Summer 2012):

Haiyang Chao and YangQuan Chen. "*Remote Sensing and Actuation Using Unmanned Vehicles*" Wiley-IEEE Press (To appear in market in mid-2012). ~210 pages.
http://www.wiley.com/WileyCDA/WileyTitle/productCd-1118122763.html

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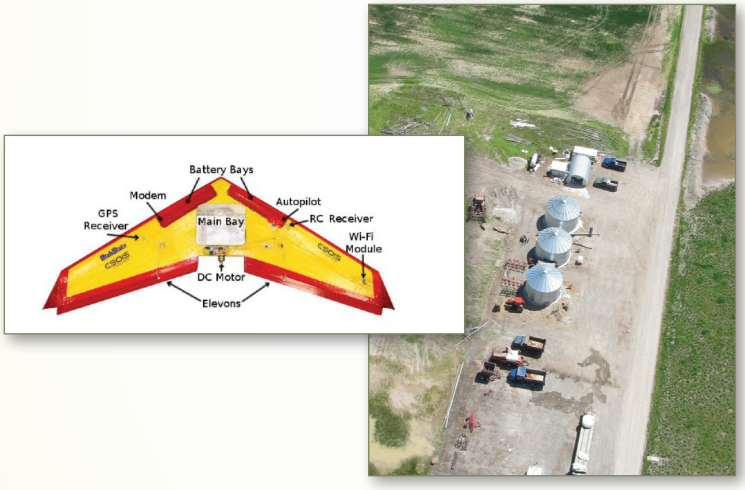
Remote Sensing AND Actuation Using Unmanned Vehicles



Haiyang Chao ▪ YangQuan Chen

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