Center for Precision & Automated Agricultural Systems




2017

Center for Precision

&

Automated Agricultural Systems

Our Mission:

"We strive to develop a World preeminent and Washington relevant research and educational program in the areas of agricultural automation and precision farming. Our mission is to provide a venue for:

- ***High impact research outcomes for our stakeholders; the Washington agricultural community***
- ***True trans-disciplinary collaboration within WSU and World-wide***
- ***High quality educational and research experiences for our students***
- ***Incubation and development of new ideas relevant in an entrepreneurial climate"***

Acknowledgement of Support

"The research projects listed in this report were supported in part by Washington State University Agricultural Research Center federal Hatch formula funds, Accession No. 1005756, 1001246 & competitive grant funds 1008554, 100339, 1004606, 228635, and 1003828, received from the U.S. Department of Agriculture National Institute for Food and Agriculture (NIFA) and by the Washington State Tree Fruit Research Commission (WTFRC), the Washington Wine Commission and Washington Association of Wine Grape Growers, the Fresh Pear Committee, and the Washington Red Raspberry Commission. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture or any other funding agencies."

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CPAAS At a Glance

The Center for Precision and Automated Agricultural Systems (CPAAS) was designed to offer a framework for agriculture automaton and precision agriculture efforts at Washington State University. To create a critical mass of expertise, CPAAS has three core faculty comprised of Qin Zhang, with expertise in the area of mechatronics and automation, Manoj Karkee with expertise in the areas of machine vision and agricultural robotics, and Lav Khot with expertise in the areas of precision agriculture, (ground and aerial crop sensing, data to decision support, and variable rate technologies development). In order to expand our reach to meet the needs of agriculture in Washington State and beyond, CPAAS has also recruited a diverse group of faculty affiliates from WSU Tri Cities and Pullman campuses, which include the WSU Department of Biological Systems Engineering, School of Chemical Engineering and Bioengineering, Department of Crop & Soil Sciences, School of Economic Sciences, School of Electrical Engineering and Computer Science, Department of Horticulture, School of Mechanical and Materials Engineering, and WSU Extension. Together, these faculty have met for brainstorming and team building events throughout the year to style joint philosophical intents into a few strategically well planned actions and to respond to calls for proposals, and to plan stakeholder events. A major achievement in 2017 was accomplished with the publishing of the book "Automation in Tree Fruit Production" by CABI press, which was written and edited by CPAAS affiliated faculty together with longtime external collaborators. CPAAS has succeeded in establishing international joint Centers and student/visiting scholar agreements that have extended our research efforts across the globe and given WSU CPAAS a worldwide recognition. To continue high impact research and outreach activities, the faculty came to a consensus on a 5-year plan for 2017-2022 in our 2016 retreat which includes:

* facilitating or coordinating the development of at least five transdisciplinary research proposals each year with the goal of bringing in at least $8 million extramural grants
* to edit and publish at least one technical book on the area of agricultural automation and precision agriculture
* to organize and host at least one international professional conference
* to organize or sponsor one technology expo to our stakeholders to disseminate research outcomes to general public, potential technology adopters, and end user growers
* have 3-5 research prototypes ready for commercialization

An assessment matrix for this 5-year goal has also been developed and as of January 2018 we are on track to meet these goals.

Research Focus Areas

Qin Zhang, Director
Center for Precision & Automated Agricultural Systems
Professor- Biological Systems Engineering

Dr. Qin Zhang has interests in the areas of agricultural automation, agricultural robotics, and precision agriculture. Before joining the faculty at Washington State University, he was a professor at the University of Illinois at Urbana-Champaign (UIUC) working on developing agricultural mechanization and automation solutions. Based on his research outcomes, he has authored 5 books, written 9 separate book chapters, edited three conference proceedings, published over 150 peer reviewed journal articles, presented about 300 papers at national and international professional conferences, and been awarded 11 U.S. patents. He is currently serving as the Editor-in-Chief for *Computers and Electronics in Agriculture*, the Editor for Springer Book Series on *Agricultural Automation and Control*, the Chair for Section III (Plant Production) of CIGR (International Commission of Agricultural and Biosystems Engineering), and Trustee for the Foundation Board of ASABE (American Society of Agricultural and Biological Engineers). Dr. Zhang has been invited to speak at international conferences over 20 times, including giving a talk on "smart agriculture" at the very prestigious Asian Leadership Conference in 2017 where world-renowned political leaders, global corporate CEOs and academic leaders came together in Seoul, Korea to discuss and provide possible solutions for the pressing issues that Asia is facing today. He has also been invited to give numerous seminars and short courses at more than 30 universities and research institutes and 11 agricultural equipment manufacturing companies in North America, Europe, and Asia, and has been serving as a guest or adjunct professor or external advisory board member for 9 universities in different countries.

Born in China, Dr. Zhang received his B.S. in mechanical engineering from Zhejiang Agricultural University in China, his M.S. from the University of Idaho and Ph.D. from the University of Illinois at Urbana-Champaign (UIUC), U.S.A., both in agricultural engineering. Dr. Zhang is an ASABE Fellow, a Full Member of the Club of Bologna (a World Task-force for Strategies for the Development of Agricultural Mechanization), and a John Deere Gold Metal awardee.

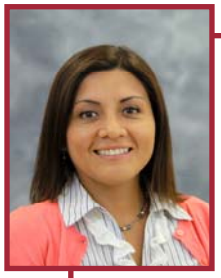
CPAAS Affiliated Faculty

David J. Brown
Associate Professor of Soil Science
Department of Crop and Soil Sciences

Dr. David J. Brown and his research group focuses on measuring, modeling and explaining the spatial variability of soil properties and processes at hillslope to regional scales. In pursuing this research, they make extensive use of digital terrain modeling, optical remote sensing, spatial statistics, and proximal soil sensing techniques (e.g. VisNIR spectroscopy).

Paul G. Carter
Associate Professor
WSU Regional Extension Specialist
Soil Science and Precision Farming

Dr. Paul G. Carter joined WSU Extension in 2005 serving the Columbia County Extension Office and a WSU Regional Extension Specialist. In 2011 he joined CPAAS as a remote sensing and dry land precision agriculture specialist working in the SE Washington area. From Purdue University, he earned his B.S. (1974) in Agriculture Mechanization, M.S. (1999) in Agronomy Remote Sensing and Soil Science, and Ph.D. (2005) in Agronomy Remote Sensing. While completing degrees at Purdue University, he worked as a staff member with the Laboratory for the Applications of Remote Sensing (LARS) and the Department of Agronomy. Paul's Extension programs include precision ag technology applications, soil quality, and cropping systems and is currently working with soil acidity, precision lime placement, and nutrient balancing. He participates in many of the county and state agricultural organizations including President of the Washington State Crop Improvement Association. Paul is editor of the Journal of Precision Agriculture and presents at regional, national and international conferences. His leadership has impacted the adoption of precision technologies in the dry land wheat production area of South East Washington State.



Karina Gallardo
Associate Professor/Extension Specialist
Puyallup Research and Extension Center
School of Economic Sciences

*Dr. **R.** Karina Gallardo* is an Associate Professor/Extension Specialist in the School of Economic Sciences. She is stationed at the Puyallup Research and Extension Center and is affiliated faculty of the Center for Precision and Automated Agricultural System at Washington State University. She holds a BS in Food Science from Universidad Nacional Agraria La Molina (Lima, Peru), a Master in Science in Agricultural Economics from Mississippi State University and a PhD in Agricultural Economics from Oklahoma State University. Gallardo's primary research and outreach program goal is to enhance value-added agribusiness opportunities for specialty crops in the state of Washington. Her areas of research focus on consumer demand analysis and economics of technological change. Gallardo is conducting research assessing consumers' preferences for fresh fruit quality, and understanding the profitability and various other factors affecting growers' adoption of new technologies, such as new cultivars, improved pest management systems, and labor enhancing mechanisms.

CPAAS Affiliated Faculty

Gwen-Alyn Hoheisel
Area Extension Educator
WSU County Extension Prosser
Executive Board Member, CPAAS

Gwen-Alyn Hoheisel started in 2006 as a faculty member with WSU Extension working in commercial tree fruit and grapes. She received her Master's degree in entomology from Pennsylvania State University in 2002, and her B.S. degree in zoology from University of Maryland in 1998. Hoheisel has focused her work on sustainable pest management, application technologies, and the use of digital media to enhance information delivery to growers. Hoheisel also sits as an ex-officio board member to five Washington tree fruit and grape commodity organizations.

Pete W. Jacoby
Professor – Crop and Soil Sciences
Affiliated CPAAS, Horticulture, Viticulture & Enology
Executive Board Member CPAAS

Dr. Pete Jacoby returned to a faculty position after serving two decades as a College Administrator in Texas, Nebraska, and Washington State. In 2014, he re-engaged in teaching, extension education, and applied research with emphasis on sub-surface micro-irrigation for high value specialty crops, including grapes, hops, and small fruit. His previous areas of research focused on studies of root system dynamics of perennial shrubs and plant eco-physiology. Although located on WSU Pullman campus, Dr. Jacoby's field research program operates from Prosser at the WSU Irrigated Agriculture Research & Extension Center. Professor Jacoby is active in the Irrigation Association, American Society of Agricultural & Biological Engineers, American Society of Enology & Viticulture, and the American Society of Agronomy. He received his M.S. and Ph.D. from the University of Wyoming and his B.S. from Texas A&M University.

Manoj Karkee
Associate Professor
Biological Systems Engineering
Executive Board Member, CPAAS

Dr. Manoj Karkee is an affiliated faculty member to the center and is an associate professor in the Biological Systems Engineering Department. Dr. Karkee was born in Nepal where he received his undergraduate degree in Computer Engineering. He then went to Asian Institute of Technology, Bangkok, Thailand in 2003 for his Master's Degree in Remote Sensing and GIS. He joined Iowa State University in 2003 and received his PhD in Agricultural Engineering and Human Computer Interaction. Dr. Karkee joined WSU in 2010 where he leads a strong research program in the area of agricultural automation and robotics with particular emphasis on sensing, machine vision and control systems. Some of his sponsored projects include apple and cherry harvesting, smart irrigation systems with IoT and big data approaches, weed control in vegetable crops, fruit tree and berry bush pruning, and solid set canopy delivery. He has published in journals such as 'Journal of Field Robotics', 'Computers and Electronics in Agriculture', and 'The Transactions of ASABE' and has been an invited speaker at several national and international conferences. He is currently serving as the Guest Editor for 'Robotics', Associate Editor for 'Transactions of the ASABE' and 'Applied Engineering in Agriculture', editorial board member for 'Image Processing in Agriculture', and advisory board member for 'Computers and Electronics in Agriculture'.

CPAAS Affiliated Faculty

Lav Khot
Assistant Professor
Biological Systems Engineering

Dr. Lav Khot is an affiliate faculty member of the CPAAS and is an assistant professor in the Department of Biological Systems Engineering. He obtained his M.E. from Asian Institute of Technology, Thailand (2004) and M.S. from Iowa State University (2006). He received his Ph.D. from North Dakota State University in 2009. Prior to joining WSU, he was postdoctoral researcher at Citrus Research and Education Center, University of Florida. His research and extension program at WSU focuses on "Sensing and automation technologies for site specific and precision management of production agriculture" with special emphasis towards integration of Proximal and Remote (Unmanned and Manned Aerial Systems) Sensing, Decision Support Systems and Information Delivery Technologies, Precise Applications of various Production Inputs, Agricultural Machinery and Processes, and Data-based Modeling. He is an active member of the ASABE since 2005 and also serves as chair of 'Precision Horticulture Engineering Working Group' of International Society for Horticultural Science.

Karen Lewis
Professor, Regional Tree Fruit Extension Specialist
Tree Fruit Extension Team Leader

Karen Lewis is a WSU Extension Regional Tree Fruit Specialist and the WSU Tree Fruit Extension Team Leader. In addition, Karen serves as the Educational Director of the International Fruit Tree Association.

She is housed in the Grant-Adams Area Extension office and CPAAS. Karen earned her B.S. degree in Plant Science and her M.S. degree in Horticulture at the University of Arizona. Karen's extension program has been guided by active participation and leadership in international, multi state and statewide academic teams and grower member industry organizations. Current program focus includes: development and integration of mechanized / labor assist technologies for tree fruit pruning, thinning and harvest; competitive apple and pear orchard systems; and the integration of technology, orchard systems and people. Lewis has secured over $2M in program support, jointly published 12 articles in horticultural and engineering journals and has been an invited speaker at conferences throughout the United States and fruit producing regions around the world.

CPAAS Affiliated Faculty

Changki Mo
Associate Professor
School of Mechanical and Materials Engineering

Dr. Changki Mo is an affiliated faculty member to the center and is an associate professor in the School of Mechanical and Materials Engineering at Washington State University Tri-Cities. He received his Ph.D. degree in Mechanical Engineering from the University of Oklahoma in 1996. Before joining WSU, Dr. Mo was Visiting Professor in the Department of Mechanical Engineering and Materials Science at the University of Pittsburgh, Pittsburgh, PA and Associate Professor in Automotive Engineering Department at Kyungpook National University (Sangju, South Korea).
His research interest includes vehicular and structural vibration control, hydraulic system control: vibration-based piezoelectric energy harvesting, micro actuators and sensors, and adaptive structures using shape memory polymers, and agricultural robotics and automation. Much of his current research focuses on robotic system design for precision agriculture and structural health monitoring, and thermal characterization of nanomaterials. He has published about 70 peer reviewed journal and conference articles, and one book chapter.

R. Troy Peters
Extension Irrigation Specialist/Associate Professor
Biological Systems Engineering

Dr. R. Troy Peters works for Washington State University and serves as the Extension Irrigation Specialist at the Irrigated Agriculture Research and Extension Center in Prosser, WA. Troy received his Ph.D. in irrigation engineering from Utah State University. Following graduation, he worked at the USDA-Agriculture Research Service Conservation and Production Research Laboratory in Bushland, TX for three years. He has been with Washington State University for over 12 years. He is also a certified agricultural irrigation specialist and is a licensed professional agricultural engineer.

Sindhuja Sankaran
Assistant Professor
Biological Systems Engineering

Dr. Sindhuja Sankaran works in the Biological Systems Engineering Agricultural Automation Engineering research emphasis area. Her research focus is on sensor technologies for crop phenotyping to support plant breeding and crop plant research applications. Her work involves development of opto-electronic and chemical sensor technologies for non-invasive, rapid and continuous monitoring of crop status to assess crop yield potential and stress tolerance/resistance.

CPAAS Affiliated Faculty

Matthew E. Taylor
Assistant Professor
School of Electrical Engineering and Computer Science

Dr. Matthew E. Taylor graduated magna cum laude with a double major in computer science and physics from Amherst College in 2001. After working for two years as a software developer, he began his Ph.D. work at the University of Texas at Austin with an MCD fellowship from the College of Natural Sciences. He received his doctorate from the Department of Computer Sciences in the summer of 2008, supervised by Peter Stone. Matt then completed a two year postdoctoral research position at the University of Southern California with Milind Tambe and spent 2.5 years as an assistant professor at Lafayette College in the computer science department. He is currently an assistant professor at Washington State University in the School of Electrical Engineering and Computer Science, holding the Allred Distinguished Professorship in Artificial Intelligence, and is a recipient of the National Science Foundation CAREER award. Current research interests include intelligent agents, multi-agent systems, reinforcement learning, transfer learning, and robotics.

Haiying Tao
Assistant Professor/Nutient Management Specialist
Crop and Soil Sciences

Dr. Haiying Tao is an assistant professor of Soil Fertility and Residue Management in the Department of Crop and Soil Sciences at WSU. Prior to joining WSU, Haiying was an associate research scientist at the University of Connecticut, working on 4R stewardship for nitrogen and best nutrient management practices for corn/soybean in different soil and climate conditions. She received her PhD in Soil Science from the University of Connecticut, MS in Agronomy from China Agricultural University, and BS in Agronomy and BS minor in Agricultural Economics from China Agricultural University. Her current research focuses on soil nutrient and residue management practices that are friendly for yield, economics, and the environment. Her extension education activities will be needs-driven by the agricultural production community in the state of Washington and neighboring states. Specific areas of research and extension include nitrogen optimization, residue management, soil acidification, soil health, precision agriculture, land application of manure, nutrient management planning.

CPAAS Affiliated Faculty

Matthew Whiting
Associate Professor/Scientist and Extension Specialist
Department of Horticulture
Executive Board Member CPAAS

Dr. Matthew Whiting is a Professor/Scientist and Extension Specialist in the Department of Horticulture. He received his Ph.D. degree from Washington State University in 2001, his M.S. and B.Sc. degrees from the University of Guelph in Canada in 1998 and 1996, respectively. Dr. Whiting leads an applied whole-tree physiology program that addresses the key horticultural and physiological issues facing the industry. Dr. Whiting's research efforts are leading the integration of mechanization and automation in tree fruit through the development of planar orchard systems that are productive, precocious, profitable, and sustainable. Since 2002, Dr. Whiting has published over 60 peer-reviewed journal articles, garnered $7.5M+ in grant funding, and given invited presentations around the globe.

Yinghui Wu
Assistant Professor
Electronic Engineering and Computer Science

Dr. Yinghui Wu researches the areas of Big Data, data management and database systems, with emphasis on graph data management and analytics. My current work has concentrated on effective data analytics in emerging applications such as knowledge graphs, network security and social newtork analysis. My broader interests include data quality, network science, web services and information visualization.

Xiao Zhang,
Associate Professor/Nutient Management Specialist
Crop and Soil Sciences

Dr. Xiao Zhang is an affiliated faculty member to the center and is an associate professor in the Voiland School of Chemical Engineering and Bioengineering. Dr. Zhang received his PhD degree from the University of British Columbia and has worked closely with papermaking and chemical industries for a number of years. Dr. Zhang is interested in the chemistry and process engineering aspects of sustainable chemicals, materials and energy production from renewable resources. Dr. Zhang is a recipient of C. Howard Smith Award from Pulp and Paper Technical Association of Canada and National Science Foundation CAREER award.

CPAAS Faculty Productivity

Impacts/Outputs	*2017*	*2012-2016*
Books Published	*1*	*3*
Book Chapters Published	*7*	*4*
Peer Reviewed Journal/Extension Articles	*22*	*108*
Students Graduated	*4*	*10**
Awards (Graduate Student)	*6*	*6*
Patents	*1*	*4*
Invention Disclosures	*2*	*8*
Commercialized		*2*
Prototypes	*2*	*8*
** (past 5 academic years)*		

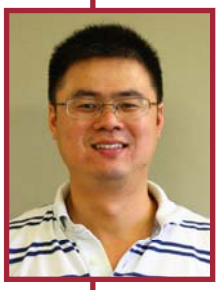
CPAAS External Advisory Committee

Jason Brown, Mercer Ranches
Walt Hough, Auvil Fruit Company
Scott Korthuis, Oxbo International
Jon Mayberry, Maberry & Maberry Berry Associates
Keith Oliver, Olsen Brothers
Gary Snyder, C&O Nursery

CPAAS Support Personnel

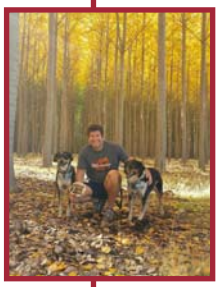
Long He
Research Engineer

Dr. Long He is a research engineer in the CPAAS. He received his Ph. D from Yanshan University in China in 2010, and his B.S from the same University in 2003. Dr. He joined Dr. Qin Zhang's research group as a postdoctoral research associate in 2010, and then moved University of California at Davis in 2013 working in the Dr. Stavros Vougioukas' research group as a postdoctoral scholar. In 2015, Dr. He came back to CPAAS as a research engineer. Dr. He's research interests include agricultural mechanization and automation, electro-hydraulic systems in agricultural machinery, and so on. He has been publishing in such journals as "Transactions of the ASABE", "Biosystems Engineering", "Applied Engineering in Agricultural"and "HortScience".



Longsheng Fu
Adjunct Faculty, Visiting Postdoctoral Research Associate

Dr. Longsheng Fu is an Adjunct Faculty in the Center for Precision & Automated Agricultural Systems (CPAAS) of Washington State University (WSU) and an Associate Professor in the Northwest A&F University (NWAFU). He received his Ph. D degree from Hokkaido University in Japan in 2012, and his M.S. and B.S degree from China Agricultural University in 2009 and 2006. Dr. Fu joined NWAFU in 2012, and then came to CPAAS in 2017. Dr. Fu's research interests include agricultural automation and robotic harvesting, fruit intelligent sensing, machine vision and deep learning, and so on. He has been publishing in such journals as "Computers and Electronics in Agriculture", "Sensors", "International Journal of Agricultural and Biological Engineering", "Agricultural Engineering International: CIGR Journal" and etc. He also has been invited to review papers in seven different journals and awarded the "Outstanding Contribution in Reviewing" of the "Computers and Electronics in Agriculture".



Patrick Scharf
Engineering Technician III/Shop Manager

Patrick Scharf earned his B.S. in Animal Science from the University of Wisconsin-Madison in 1999 and his M.S. in Biological and Agricultural Engineering from Washington State University in 2016. Patrick's roles at CPAAS includes facilities management, research project management, project design consulting, project fabrication, safety coordination, shop management, vehicle fleet management, and administrative assistance with issues pertaining to his various roles. In his free time Patrick enjoys spending time with his happy companions, Hank and Bear, doing outdoor activities including hiking, camping, kayaking, skiing, and running. He has run races on four corners of the continental U.S. and places in between, with plans for expanding his running to venues around the world.

Linda Root
Finance/Budget Manager

Linda Root came to WSU in 2006 with of seventeen years of experience in small business management. She helped facilitate the spin-off of AgWeatherNet and has been working to assist the growth of CPAAS. She has an AA degree in Business Administration from Columbia Basin College and performs functions in Center finance management, grant management, purchasing, travel, event planning as well as Principal Assistant to the Director.

CPAAS Graduate Students

Ph.D. and M.S. students come to us from the U.S. and around the world, as both WSU students and joint visiting students earning credit at their home universities, helping bring our cultures together while searching for solutions to agricultural problems world wide .

Haitham Bahlol

Ph.D. anticipated Spring 2019

Studies: *Developing new technological solutions to reduce spray drift in tree fruit crops.*

Santosh Bhusal

Ph.D. anticipated Fall 2019

Studies: *Bird deterrence in wine grapes using unmanned aerial systems (UASs).*

3rd place Winner of 2017 Biological Systems Engineering 512 Poster Competition

Lin Chen

Ph.D. anticipated Fall 2019

Studies: *Automated weed control in vegetable crops.*

Zongmei Gao

Ph.D. anticipated Fall 2019

Studies: *Application of hyper-spectral imager for biotic & abiotic stress detection in specialty crops.*

Kapil Khanal

M.S. anticipated Spring 2018

Studies: *Cane management in red raspberry: a proof of concept towards mechanization.*

Yaqoob Majeed

Ph.D. anticipated Fall 2019

Studies: *Mechanical / automatic solution for the trellis training of apple trees.*

1st place Winner of 2017 Biological Systems Engineering 512 Poster Competition

Rajeev Sinha

Ph.D. anticipated Spring 2019

Studies: *Solid set canopy delivery system (SSCDS) customized for apple orchards and vineyards.*

Winner of 2017 Biological Systems Engineering Outstanding Graduate Student (Arnie & Marta Kegel Endowed Fellowship)

Jing Zhang

Ph.D.—Visiting Student

Studies: *Branch detection and localization for apple shake and catch harvesting machine using deep learning.*

Xin Zhang

Ph.D. anticipated Spring 2020

Studies: *Intelligent canopy management for mechanized precision tree fruit production.*

Winner of 2017 Biological Systems Engineering Outstanding Graduate Student (Arnie & Marta Kegel Endowed Fellowship)

Yanru Zhao

Ph.D.—Visiting Student

Studies: *Precision farming, with special focus on crop sensing technologies.*

CPAAS 2016/2017 Academic Year Graduates

Momtanu Chakraborty, M.S.

Studies: *Developing rapid crop canopy assessment methods using ground and aerial remote sensing techniques*

2nd place Winner of 2017 Biological Systems Engineering 512 Poster Competition

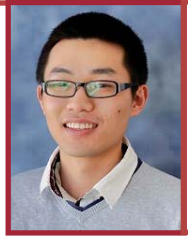
Ahbisesh Silwal, Ph.D.

Studies: *Machine vision for robotic apple harvesting*

ASABE Boyd-Scott Graduate Research Award, 2017 and WSU Commercialization Gap Fund

Parish Nalavade, M.S..

Studies: *Development and assessment of application technologies and spray-drift quantification technique in tree-fruit crops*



Yunxiang Ye, Ph.D.

Studies: A maneuverability study on a wheeled bin management robot in tree fruit orchard environments

CPAAS Visiting Scholars

Global engagement is essential to the mission of the University for achieving a world-class environment for research, scholarship, education, the arts, and engagement. Through international Memoranda of Understanding (MOUs) and International Agreements (IAs), the University fosters a network of students, alumni, teaching, and research colleagues and leaders with experiences, networks, and commitments to share in the development and execution of activities beneficial to the University, the state of Washington, and the world .

Kun cai, Ph.D.

College of Electronic Engineering, South China Agricultural University

Li Dai, PH.D.

Dept. of Management Science and Engineering, School of Economics and Management, Zhejiang Sci-Tech University

Quifang Dai, PH.D.

College of Electronic Engineering, South China Agricultural University

Jieli Duan, PH.D.

Engineering Basic Teaching and Training Center, South China Agricultural University

Hongjie Liu, PH.D.

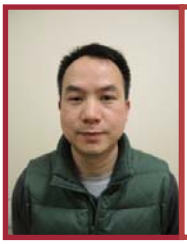
Mechanical and Electrical College of Hebei Agricultural University

Hongxing Peng, PH.D.

College of Mathematics and Informatics, South China Agricultural University

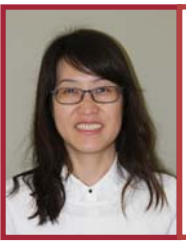
Yuanyuan Shao, Ph.D.

School of Mechanical and Electronic Engineering, Shandong Agricultural University



Yunlong Wei, Ph.D. Candidate

Dept. of Electronic Information Engineering, School of Physics and Information Engineering, Fuzhou University



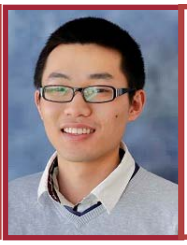
Yanlei Xu, Ph.D.

College of Information and Technology, Jilin Agricultural University

CPAAS Post Doctoral Research Associates

Azeem Khan, Ph.D.

Visiting Fulbright Scholar
University of Ruhuna
Sri Lanka



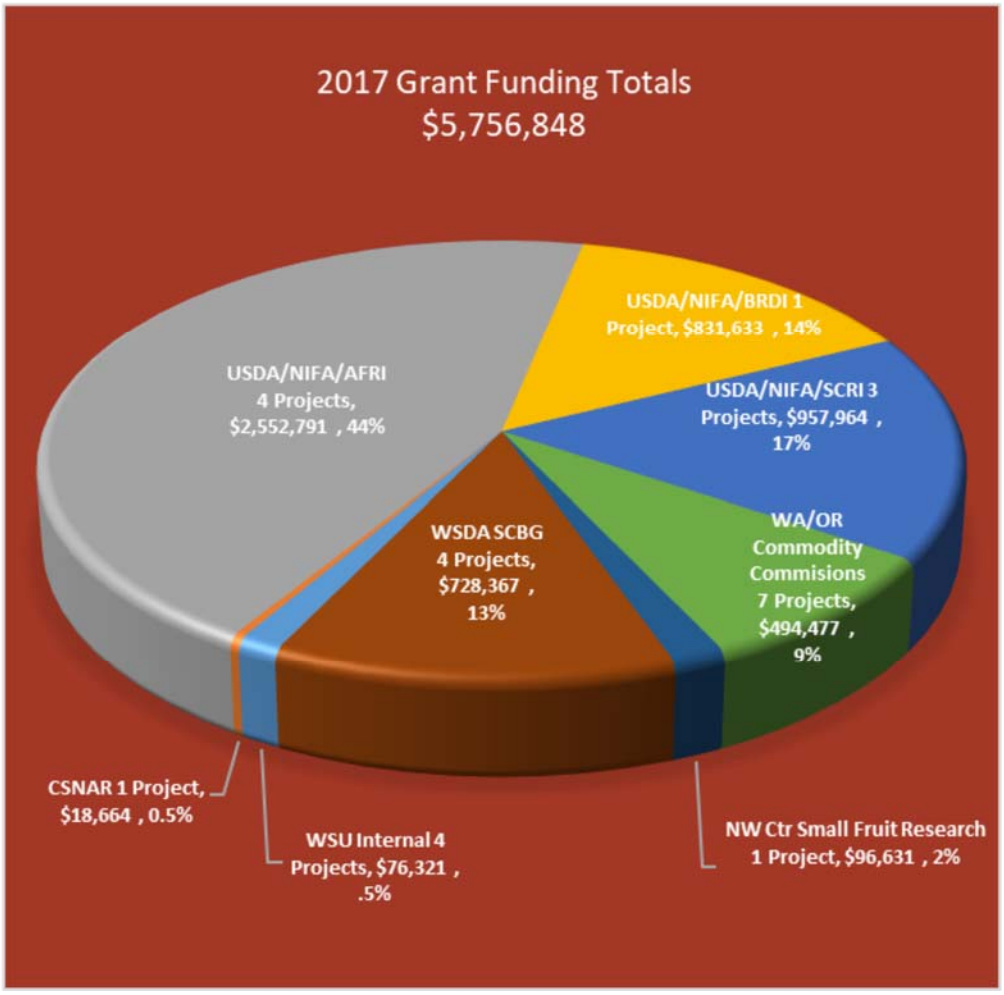
Yunxiang Ye, Ph.D.

Post Doctoral Research Associate

Sponsored Projects 2017

IN TREE CROP LOAD ESTIMATION OF APPLES WITH SMARTPHONE, CPAAS LEAD: MANOJ KARKEE	$15,389	WSU OC
ERI: A PROOF OF CONCEPT SYSTEM USING AUTONOMOUS UAS, CPAAS LEAD: MANOJ KARKEE	$8,811	WSU ARC
ERI: ADAPTING SATELLITE-BASED METHODS FOR ESTIMATING WATER USE AND CROP-WATER STRESS TO HIGH RESOLUTION IMAGES FROM SMALL UAS CPAAS LEAD: R.T. PETERS	$39,701	WSU ARC
RAPID SENSING OF DAIRY MANURE NUTRIENTS FOR PRECISION APPLICATIONS IN AGRICULTURAL PRODUCTION, CPAAS LEAD: LAV KHOT	$18,664	CSNAR
LOW ENERGY PRECISION APPLICATIONS: UAS BASED RAPID EVALUATION FOR CROP AND SITE SPECIFIC SYSTEM ADAPTATION IN THE PACIFIC NORTHWEST, CPAAS LEAD: LAV KHOT	$27,500	SWWRC
AUTOMATED HARVESTING OF TREE FRUIT, CPAAS LEAD: MANOJ KARKEE	$548,735	USDA/NIFA/AFRI
SHAKE CATCH HARVESTING FOR FRESH MARKET APPLES, CPAAS LEAD: MANOJ KARKEE	$495,480	USDA/NIFA/AFRI
INTELLIGENT INORCHARD BIN MANAGING SYSTEMS FOR TREE FRUIT, CPAAS LEAD: QIN ZHANG	$1,010,169	USDA/NIFA/AFRI
CELLULOSE NANOCRYSTALS FOR PREVENTING FROST DAMAGE IN TREE FRUITS AND GRAPES, CPAAS LEAD: QIN ZHANG	$498,407	USDA/NIFA/AFRI
PRECISION SUB-SURFACE IRRIGATION TO REGULATE WINE GRAPE PHYSIOLOGY, CPAAS LEAD: PETE JACOBY	$96,631	NW CTR SMALL FRUIT RESEARCH
CONVERSION OF HIGH-YIELD TROPICAL BIOMASS INTO BIOFUELS, CPAAS LEAD: QIN ZHANG	$831,633	U OF HAWAII USDA/ NIFA/BRDI
STEAM-GENERATED SUPPLEMENTAL HEAT THERMOTHERAPY, CPAAS LEAD: LAV KHOT	$249,859	U OF FLORIDA USDA/NIFA/SCRI
SOLID SET CANOPY DELIVERY SYSTEMS, CPAAS LEAD: LAV KHOT	$315,163	MI ST UNIV USDA/ NIFA/SCRI
WEED CONTROL IN VEGTABLE CROPS, LEAD: MANOJ KARKEE	$392,942	UC DAVIS USDA/ NIFA/SCRI
DETECTION FOR APPLE BITTER PIT MANAGEMENT, CPAAS LEAD: LAV KHOT	$180,628	WSDA SCBG
EFFECTIVENESS OF FOLIAR CALCIUM APPLICATIONS IN BITTER PIT MANAGEMENT, CPAAS LEAD: LAV KHOT	$20,876	WTFRC
DETERMINING BLUEBERRY COLD HARDINESS IN WA, CPAAS LEAD: GWEN HOHEISEL	$37,637	WA BLUEBERRY COMM.
TRELLISING DEMO PLOT DEVELOPMENT FOR EVALUATING AUTOMATION TECHNOLOGY, CPAAS LEAD: MANOJ KARKEE	$209,927	WRRC
COMMERCIALIZATION GAP FUND, LEAD: MANOJ KARKEE	$12,420	WSU OC
MAXIMIZING CONCORD GRPE PRODUCTION WITH SUB-SUFACE MICRO-IRRIGATION, CPAAS LEAD: PETE JACOBY	$43,767	WA CONCORD GRAPE COMM.
DEEP SUB-SURFACE MICRO-IRRIGATION TO INCREASE WATER USE EFFICIENCY IN WASHINGTON VINEYARDS, CPAAS LEAD: PETE JACOBY	$249,971	WSDA SCBG
INCREASED WATER USE EFFICIENCY IN WA VINEYARDS, CPAAS LEAD: LAV KHOT	$47,817	WSDA SCBG
POTATO POSTHARVEST & LOSS MGMT IN BULK STORAGE, CPAAS LEAD: SINDHUJA SANKARAN	$249,951	WSDA SCBG
ASSESSMENT OF APPLICATION TECHNOLOGIES SPECIFIC TO THE WESTERN PACIFIC NORTHWEST BLUEBERRIES, CPAAS LEAD: GWEN HOHEISEL	$14,925	OR BLUEBERRY COMM
ASSESSMENT OF APPLICATION TECHNOLOGIES IN WINE GRAPES, CPAAS LEAD: GWEN HOHEISEL	$139,845	WSGWRC

Sponsoring Agencies



WASHINGTON Red Raspberries

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

WASHINGTON TREE FRUIT RESEARCH COMMISSION

NORTHWEST CENTER FOR SMALL FRUITS RESEARCH

WSDA

Selected Research Project Summaries

Integrated Systems Research and Development in Automation and Sensors for Sustainability of Specialty Crops

Funding Agency: USDA NIFA (Hatch Multi State Project)
WSU Investigators: Qin Zhang; Karen Lewis and Manoj Karkee

Specialty crop producers have a need for automated production and post-harvest equipment. Aiming at filling this need by providing required research and development for such equipment, this project adapts biological concepts associated with specialty crop production, harvest, and postharvest handling into quantifiable parameters that can be sensed, develops sensors and sensing systems that can measure and interpret the parameters, and enhances the design and evaluation of automation systems that incorporate varying degrees of mechanization and sensors to assist specialty crop industries with labor, management decisions, and reduction of production costs. The success of the project will be measured by the number of prototypes the participants develop, patents they file, and assistance they provide to industry in the process of developing commercial products.

Intelligent Agricultural Systems for Specialty Crop Production

Funding Agency: UDSA NIFA (Hatch)
WSU Investigators: Qin Zhang; David Brown, Manoj Karkee; Lav Khot

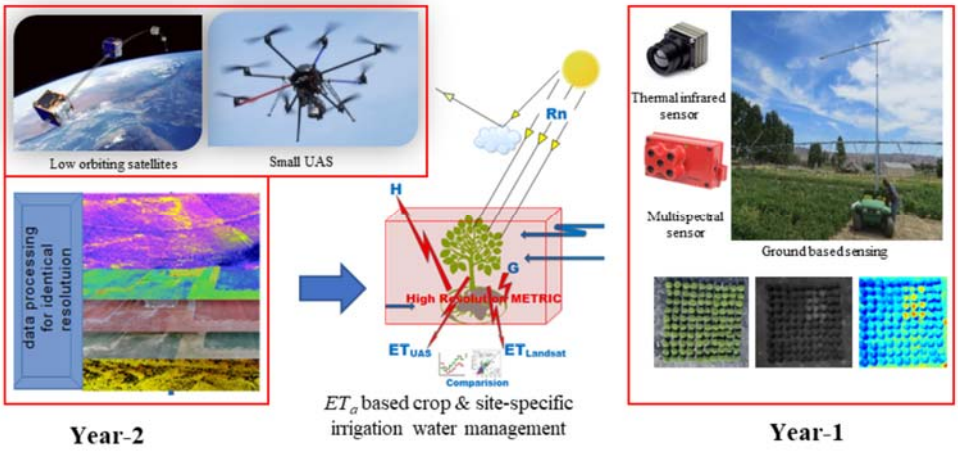
The recent advancement of intelligent agricultural equipment (IAE) technology has made such equipment practical and applicable for agronomic crop production. However, there are still many special challenges to be solved before the technology can be practically applied to specialty crop production. The primary focus of this project is to remove such challenges to make IAE technology practical and applicable for specialty crops production. Specific objectives of this project are to develop mechanization and robotic solutions for production of a wide range of specialty crops, including, but not limited to, fruits and vegetables, hops, grapes and berries, and nursery crops; to find automated solutions for disease/pest monitoring, scouting and controlling in specialty crop production; to develop core technologies for computer-aided worksite management, from data collection and analysis to decision-making support; and to create effective methods for demonstrating and delivering the research outcomes to the stakeholders.

Selected Research Project Summaries

Adapting Satellite-Based Methods for Estimating Water Use and Crop-Water Stress to High Resolution Images from small UAS

Funding Agency: WSU- Emerging Research Issues
WSU Investigators: R. T. Peters, L. R. Khot, C. Stockle

There is significant concern about the increased frequency and severity of drought in the Pacific Northwest. This is expected to become a persistent issue if climate conditions continue to change as predicted. Growers will need to adapt to these water shortages with precision irrigation water management and tools will be needed for implementation. This project proposes to evaluate the suitability of high spatial & temporal resolution remote sensing data from small unmanned aerial system [UAS] and or low-orbiting satellites for use with ***METRIC*** *(Mapping Evapotranspiration at high Resolution with Internalized Calibration)* and simple crop model algorithms. METRIC is an energy balance, crop water use model. It was developed for use with satellite imagery for large scale, low resolution applications. We propose to adapt METRIC for use for smaller scale, high resolution applications using imagery from UAVs for site-specific irrigation water management for high value crops grown in Washington State.



Assessment of application technologies in wine grapes

Funding Agency: The Washington State Grape and Wine research Program
WSU Investigators: Gwen Hoheisel, Michelle Moyer, and Lav Khot

This study compares three different sprayer designs (electrostatic, directed sprayer with disc core nozzles, and directed sprayer with air shear nozzles) for their efficacy in disease management as it relates to both general coverage and coverage types specific to different fungicide modes of action, efficiency of operation, and ease of use. A feature that makes this project unique is that a PhD student will be supported by Graduate Extension Assistantships, grant funding, and private funding from the 'Altria and Ste. Michelle Wine Estates Viticulture and Enology Fund'. This student will work with the PIs to develop a component of a 3-part curriculum for viticulture technicians.

Selected Research Project Summaries

Balancing Concord Production and Water Use with Root-zone Micro-irrigation

Funding Agency: WA State Concord Grape Research Committee
WSU Investigators: Pete W. Jacoby, Sindhuja Sankaran, Lav Khot, Markus Keller, and Troy Peters

A Concord grape vineyard has demonstrated the potential to remain productive during extended periods of drought through the use of subsurface irrigation with considerable savings in water compared to surface drip irrigation. During the first two years of this project, plant water stress, as determined by mid-day measurement of stem water potential, was substantially less in plots receiving subsurface irrigation at the 2- and 3- depths than in surface and 1-foot depths. However, by end of 2016, grape clusters were consistently heavier with increase depth of irrigation delivery, with lightest clusters from the surface drip irrigation treatment and the heaviest from the 4 foot depth. This finding suggests that vines were able to develop deeper roots capable of extracting moisture from the full range of the soil profile. During 2017, growing conditions that resulted from above average precipitation and cooler temperatures compromised the various irrigation treatments and data was not taken at time of harvest. This study will continue if funding is provided to allow data collection during the 2018 growing season.

Cellulose NanoCrystals for Preventing Frost Damage in Tree Fruits and Grapes

Funding Agency: USA NIFA
WSU Investigators: Qin Zhang; Changki Mo; Mathew Whiting, and Xiao Zhang

The goal of this research is to synthesize a novel Cellulose NanoCrystals (CNC) based dispersion that can be applied as a spray agent on tree fruit buds to prevent the frost damage. Low temperature damage to plant tissues poses a serious perennial threat to the sustainable and profitable production of many specialty crops. Indeed, a single freeze or frost event can result in crop losses in the millions, literally overnight. A recent breakthrough at Washington State University has yielded a unique opportunity for using CNC to protect sensitive fruit tree buds. This research has the potential to create a significant new market for CNC requiring commercial production and distribution of large volumes - the projected annual demand for CNC applied at 2 to 4 kg/acre to apple and sweet cherry in Washington State alone is compelling at 500 to 1000 tons. A multi-disciplinary team encompassing expertise in horticulture, agriculture, chemistry, chemical engineering and mechanical engineering has been assembled to conduct this demonstration project. The expected outcomes of this innovative project will include a means to quantify the thermal properties of the Cellulose NanoCrystals (CNC), an effective spraying method for tree fruit bud application, and relationship between cold-hardiness and CNC treatment.

Selected Research Project Summaries

Conversion of High-Yield Tropical Biomass into Sustainable Biofuels

Sponsor Agency: USDA NIFA BRDI
WSU Investigators: Qin Zhang and Manoj Karkee

In this project, we studied the performance of existing sugarcane harvester in harvesting various types of tropical biomass crops including sugarcane, energy cane and Bana grass. These tests were carried out in Maui, Hawaii in collaboration with Hawaii Commercial and Sugar Company. Based on these baseline studies, we identified various ways the performance of the harvesters could be improved. In addition, a physical simulation study has been carried out at WSU Prosser to optimize energy consumption in biomass base cutting.

Crop Signaling for Automated Weed/Crop Differentiation and Mechanized Weed Control in Vegetable Crops

Funding Agency: USDA NIFA (SCRI)
WSU Investigators: Manoj Karkee and Qin Zhang,

Stakeholders have identified effective and economical weed management techniques as a high research priority in vegetable crops, and a critical need in specialty crop production systems. Intra-row weeds decimate vegetable crops and add sharply to the cost of farm management because herbicide application against them is often inefficient and/or they require removal by hand labor. Our long-term goal is to develop and integrate various novel engineering and automation technologies to develop cost-effective weed control systems for intra-row weed management in vegetable crops. In this project, we are developing new technologies for precise intra-row weed control and crop thinning using precision planting, crop signaling and new weed detection and actuator technologies. Component technologies will be developed at UC Davis and the University of Arizona as well before integrating them into effective and efficient weed management strategies for growers in WA, CA, AZ and other vegetable growing areas. This system is expected to reduce the need for both hand labor and herbicides while increasing productivity, profitability and long term sustainability of vegetable production. Both organic and conventional growers will benefit greatly from our game-changing research.

Selected Research Project Summaries

Deep Subsurface Micro-irrigation to Increase Water Use Efficiency in WA Vineyards

Funding Agency: WSDA Specialty Crop Block Grant Program
WSU Investigators: Pete W. Jacoby, S. Hossein Sadeghi, Sindhuja Sankaran, and Lav R. Khot

During three growing seasons from 2015 through 2017, vines receiving direct root-zone (DRZ) irrigation at rates reduced to 60, 30, and 15% of commercial drip irrigation (DI) exhibited greater crop water use efficiency than did vines under surface drip irrigation. Each growing season presented climatic differences that resulted in varying levels of water stress on grape development and quality, as well as vine vigor. Overall, DRZ drip irrigation demonstrated the ability to maintain a level of grape production equivalent to no less than 70% of commercial production, but with considerable savings in water resources. No differences were found among depths of DRZ delivery of water from 1-,2-, or 3-foot below soil surface. This project produced one peer reviewed publication during 2017 and several more are anticipated to be published during 2018. Funding for this project will terminate in April 2018 but the final report for the project has been extended for 6 months to allow incorporation of data from the 2018 growing season.

Human machine collaboration for automated harvesting of tree fruit

Sponsor Agency: NSF-USDA-AFRI NRI
WSU Investigators: Manoj Karkee, Karen Lewis, Changki Mo and Qin Zhang

Apple harvesting is not only labor intensive but also a time critical task requiring right amount of semi-skilled workforce at right time. The lack of mechanized harvesting system threatens the future of fresh market apple production because of the decreasing availability of farm labor force. Despite the research and development efforts over the last several decades, no commercially viable robotic harvesting systems have been available yet, primarily because of the challenges posed by unstructured farming environment. This project investigated novel approaches to overcome the challenges in robotic apple harvesting. First, a machine vision system capable of identifying apples in a naturally clustered and occluded conditions was developed. Artificial lighting was used to provide capability for night time operation. Then, hand picking dynamics were studied to understand optimal picking patterns and forces required to detach apples. Based on this study, an under-sensed power grasp end-effector was designed. Both mechanical and soft-material based hands were investigated. Vision system, robotic arm, and end-effector were then integrated and evaluated in a commercial orchard in Prosser, WA. Results showed a huge potential for in-field automated robotic harvesting system capable of accurately identifying, localizing, and picking fruit at relative high speed.

Selected Research Project Summaries

In-field Sensing and Decision Support System to Prevent Cherry Fruit Cracking due to Rainwater

Funding Agency: WSU-CAHNRS Emerging Research Issues
WSU Investigators: Lav Khot, Troy Peters, Matthew Whiting, Qin Zhang and David Granatstein

Fruit cracking due to early summer rain remains the key concern for fresh market sweet cherry growers worldwide. Existing mechanical rainwater removal techniques (e.g. orchard sprayers or fans, aerial helicopters) are used by growers but there has been little systematic research on when and how much water needs to be removed from cherry canopies and the effectiveness of water removal. This project therefore focused on developing an intelligent in-field sensing and decision support system that can aid growers in managing canopy rainwater removal. Project also evaluated mid-sized unmanned aerial helicopters, an emerging technology, as a viable alternative to manned helicopters flights to disperse canopy rainwater. Developed in-field sensing system was used to conduct field experiments for optimizing mid-sized unmanned helicopter flights in modern cherry architectures and also to evaluate efficacy of an orchard air-blast sprayer in rainwater removal from such canopies.

Intelligent Bin-Dog System for Tree Fruit Production

Funding Agency: USA NIFA AFRI NRI
WSU Investigators: Qin Zhang, Karen Lewis, and Long He

Harvest is the most labor-intensive operation in tree fruit orchards, requiring heavy use of seasonal labor. However, the increasingly severe shortage of labor force threatens the sustainability of the tree fruit industry in the United States. To combat this problem, the tree fruit industry needs technological innovations to assist growers in maintaining a competitive position in the global marketplace. Preliminary conceptual development field trials indicated that the productivity of fruit picking could be improved by 50% if the collection bins within harvesting sites could be better managed. This research aims to develop an intelligent bin-managing system supported by a robotic self-propelled fruit bin carrier. A self-propelled bin managing robot research prototype has been developed, fabricated and tested in both laboratory and orchard environments. This prototype consists of a passive mechanical suspension system and a four-wheel independent steering (4WIS) system. Supported by a multi-sensor based navigation system and an intelligent steering strategy selection algorithm, this prototype is able to switch among different steering methods to guide it accurately following the desired path under different situations. It is expected that the completion of these activities will lead to a successful development of an intelligent in-orchard bin-managing system. When commercialized, the technology can reduce labor use in bin managing during harvest season while improve the bin-managing efficiency.

Selected Research Project Summaries

In-tree apple crop-load estimation with smartphones

Sponsor Agency: WSU Office of Commercialization
WSU Investigators: Karkee, M.

Crop-load estimation is an important management tool for apple growers. It is crucial for the efficient management of pre/post-harvest operations such as labor and equipment requirements for harvesting and transporting fruit from the orchard to packing house. Various research efforts around the world have developed machine vision systems for apple detection and counting, but the sensors (e.g. industrial cameras and GPS units) and platforms/ machines used for crop-load estimation research have been complex and expensive while also requiring a skilled and dedicated operator to collect field data. These limitations of the sensing system and platforms have created a bottleneck for commercial adoption of the crop-load estimation technology despite a good level of fruit counting and sizing accuracy. In this project, we are developing a simple and low-cost yet practical approach for apple crop-load estimation. A Software Application (App) was developed that used the sensors (cameras and GPS) of a mobile device (e.g. a smartphone) to acquire images in apple orchards. These images are processed in near-real time for detection, counting, and sizing of apples. The App is then be used to scan and count fruit in a number of sample trees in a plot, which will be used as an input to a geostatistical model developed for estimating crop-load in orchards. A preliminary work conducted in a commercial orchard with the newly developed App showed an accuracy of 98% in estimating number of apples in a fruiting wall orchard.

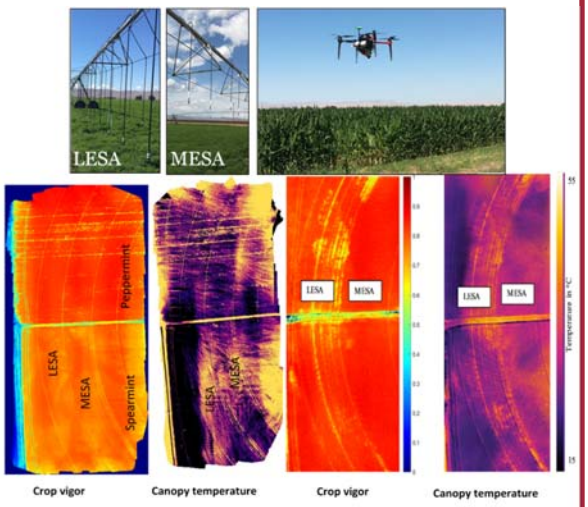
Machine Vision System Development for Shake and Catch Harvesting

Funding Agency: CPAAS
WSU Investigators: Manoj Karkee, Jing Zhang

This project was aimed at identifying branches of apple and cherry trees for harvesting fruit using mechanical limb shakers. Automation in apple and cherry harvesting using mechanical shakers requires sensors that can guide robotic arm to the branches. The machine vision system will help to identify branches for locating shaking points. Color cameras (including stereo pairs) were used to acquire images of cherry trees. Image processing techniques (including deep learning) were then used to segment branches from the background. Because branches were only partially visible due to occlusion by leaves and fruit (particularly for cherries during harvest season), information on fruit location was also integrated with branch information to reconstruct entire tree branches. Finally, shaking points were located in the 3D canopy structure using stereo images or 3D camera images.

Low Energy Precision (/Spray) Applications: Unmanned Aerial System based Rapid Evaluation for Crop and Site Specific System Adaptation in the Pacific Northwest

Funding Agency: WRC State of Washington
Investigators: Lav Khot, R. Troy Peters (WSU team) and Howard Neibling



Water inevitably is the most valuable resource of the western states and is foundation for billion-dollar agricultural industry. Keeping in view the preset situation of water and future needs under changing climate, growers need to adopt new/improved irrigation technologies, like Low Elevation Spray/Precision Application (LESA/LEPA). Such technologies have grower adoption concerns related to water use efficiencies as the canopy and air temperature driven evapotranspiration effects are unknown. This project thus focused on evaluating LESA and MESA irrigated corn and mint (spearmint and peppermint) crop using small unmanned aerial system integrated multispectral and thermal imaging techniques. Imagery was acquired throughout the season at various crop growth stages to understand canopy vigor and temperature differences. In corn production, MESA had more crop vigor and a cooler canopy than LESA. Results were anticipated, as the sprinkler heads used in LESA were being pulled off, causing the weighted hose to damage the corn. In mint production, LESA irrigated canopies were vigorous and cooler compared to MESA. Overall, studies showed promising results on suitable use of the high resolution remote sensing technology in evaluate those irrigation techniques for site- and crop specific adaptation.

Mechanizing Red Raspberry Pruning and Tying System

Funding Agency: Washington Department of Agriculture and WRRC
WSU Investigator: Manoj Karkee

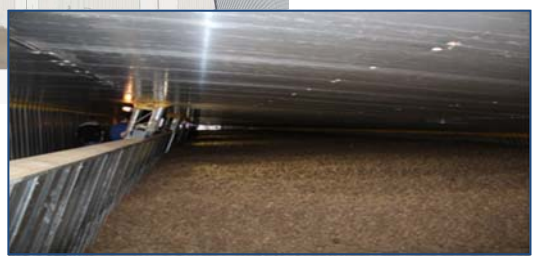
Washington State is the biggest producer of red raspberries in the United States. Mechanization has already been achieved in harvesting the crop, but other agricultural practices such as pruning and bundling of canes remain highly labor intensive. In this work, an automated cane bundling and tape wrapping mechanism was developed and evaluated in the field environment to gather one year old canes (primocanes) and tie them together. In addition, we have been developing methods to identify two years old canes (floricanes) for pruning. A spectroscopy sensor (400 to 2500 nm range) and hyperspectral imaging system (450-950 nm range) was used for scanning red raspberry canes. Next, image classification techniques were investigated to differentiate primocanes and floricanes. The classification methods achieved an accuracy of 93.1% in detecting floricanes.

Selected Research Project Summaries

Novel sensing for potato postharvest quality and loss management in bulk storages

Funding Agency: WA USDA/ AMS/ Specialty Crop Block Grant
WSU Investigators: S. Sankaran, L.R. Khot, B. Schroeder

Washington State is a major potato producer in the U.S. However, postharvest potato management is a challenge to stakeholders with bulk storage losses of about 6%. Several diseases affect potato quality during storage. Presently, managers' lack state-of-art sensing tools to detect and manage storage diseases at early stages. Existing methods involve periodic visible symptom monitoring, air sniffing for anomalies by personnel, plus sparse temperature probes for hot spot monitoring that are somewhat subjective, labor intensive, and inadequate. Thus, we propose to develop novel sensing technologies for early disease detection in bulk-stored potatoes. This will: 1) offer an unprecedented aid for growers to implement appropriate potato rot detection and management practices by manipulating temperature, humidity, and airflow to limit pathogen growth and development; and 2) help reduce the postharvest potato storage losses through early processing. The technology we develop can also be adapted for other specialty crops (e.g. onions) grown in the region. Specific objectives of this project are to investigate portable field asymmetric ion mobile spectrometry, chemosensor, and thermal infrared imaging based sensing modules for trace level volatile biomarkers and anomaly detection associated with potato rots. Our primary focus is on Pythium leak and soft rot, two predominant pathogens associated with potato storage losses. Research will be conducted using Russet Burbank, an industry standard variety for French fries, and Ranger Russet, most vulnerable variety to storage issues.



Precision Sub-surface Irrigation to Regulate Wine Grape Physiology

Funding Agency: Northwest Center for Small Fruit Research
WSU Investigators: Pete W. Jacoby, Sindhuja Sankaran, Lav Khot, Markus Keller, and Troy Peters

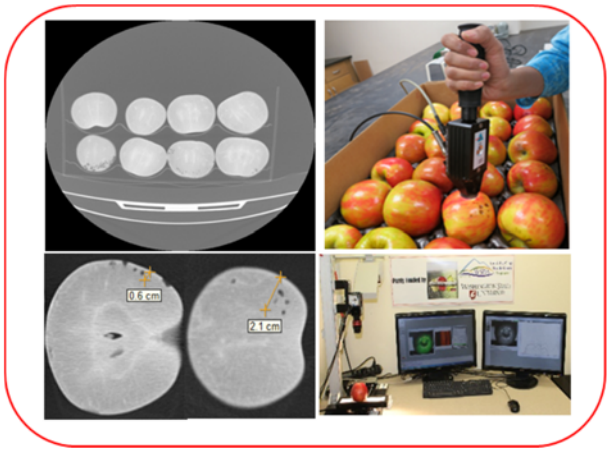
Use of DRZ sub-surface drip irrigation has been evaluated over three growing seasons. This unique system does not involve the use of buried drip lines but, rather, delivers the drip irrigation through a pair of PVC delivery tubes inserted either side of the vine to a depth of 1-, 2-, or 3-foot depth. Our hypothesis was that considerably less water would be needed to maintain vines through the avoidance of water loss from surface evaporation and use by weeds. A primary concern was the ability of established vines to reallocate carbon resources to develop deeper root systems for accessing soil moisture delivered at depths below 18 inches where the bulk of roots have been reported when vines are supported by surface drip irrigation. Digital images obtained by rhizotron techniques have affirmed the capacity of vines to shift carbon resources for deep root development and these data are being prepared for publication. This project funding ended at the end of September 2017 and a final report is nearing completion to be submitted to the funding agency.

Selected Research Project Summaries

Rapid Detection Technologies for Pre- and Post-Harvest Apple 'Bitter Pit' Management

Funding Agency: WA AG/ USDA/ AMS/ Specialty Crop Block Grant
WSU Investigators; Lav Khot and Sindhuja Sankaran

This project aimed at providing sensing solutions to identify bitter pit disorder in fresh market apples, and prevent storing and packaging of the affected apples. The computer tomography (CT)-based imaging, visible-near infrared (Vis-NIR) spectroscopy, hyperspectral imaging (HSI) and Fourier transform infrared (FTIR) spectroscopy techniques were evaluated on three most susceptible apple varieties ('Honeycrisp', 'Granny Smith', and 'Red Delicious') grown in the WA State. Major outcomes include: Vis-NIR, HSI, CT and FTIR sensing techniques were able to identify this disorder; CT imaging identified internal injuries in apples; Chemical composition analysis showed imbalances in calcium and magnesium content in bitter pit apples. Honeycrisp, Golden Delicious and Granny Smith showed similar trends in those imbalances; The project results have been published in six peer reviewed journals and stakeholder outreach was done through 9 presentations in different meetings and conferences. Project results translated beyond the scope and researchers (not part of this project) are using pertinent CT imaging techniques and developed image processing software in high throughput phenotyping of apple cultivars, and in evaluating role of calcium in bitter pit development & progression.



Rapid Sensing of Dairy Manure Nutrients for Precision Applications in Agricultural Production

Funding Agency: CSANR BIOAg Program, Washington State University
WSU Investigators: Pius Ndegwa, Lav Khot, and Gopi Kafle

Precision application of manure in agricultural lands entail accurate information on its nutrients. However, existing methods are unsuitable for real-time nutrient levels estimation. This project therefore explored the near infrared spectroscopy (NIRS) as a rapid, non-destructive method of composition analyses, which can analyze several nutrients simultaneously. In order to apply NIRS technology for variable manure application under field conditions, our efforts were towards identification of specific spectral bands & development of robust computing algorithms for predicting manure nutrients (i.e. total ammoniacal N, ortho P, total N, and total P).

Selected Research Project Summaries

Shake and Catch Harvesting for Fresh Market Apples

Funding Agency: USDA NIFA AFRI
WSU Investigators: Manoj Karkee, Matthew Whiting and Qin Zhang

To reduce harvest costs and dependence on labor, researchers have been seeking mechanical/robotic solutions for decades. Fruit quality and removal efficiency are the two major concerns for mechanical harvesting technology. In this work, tests were carried out with various designs of shaking and catching mechanisms for a targeted shake-and-catch harvesting system. Multiple layers of cushioned catching surfaces were used. Fruit drop tests were used to identify potential sources of bruising and to identify catching surface materials that may reduce fruit bruising. To reduce impact force on fruit during harvesting, a new catching device was designed. A dynamic test was also conducted to investigate the energy transmission to different locations in the limbs with different type of shaking mechanisms. An optimized mechanism was then evaluated for targeted shake-and-catch harvesting of various apple cultivars. It was found that the fruit removal efficiency and quality were depended on the cultivars. For the varieties tested, fruit removal efficiency varied from 70% to 90% with US Extra Fancy fruit (bruise diameter less than 12.7 mm) varying from 65% to 90%. It was found that 'Fuji', 'Jazz', and 'Pink Lady' varieties performed better in terms of fruit removal efficiency and fruit quality, showing the potential for targeted shake-and-catch harvesting of fresh market apples for certain varieties.

Solid Set Canopy Delivery Systems (SSCDS): an efficient, sustainable and safer spray technology for tree fruit

Funding Agency: USDA-NIFA SCRI (Lead: MSU)
WSU Investigators: Lav Khot and Gwen Hoheisel

To configure and adapt SSCDS for the modern canopy architectures common in the WA state, WSU team evaluated six and four different emitter/microsprayer configurations respectively in apple and grapevines. Those configurations were chosen in consultation with grower advisory members and MSU team. At three growth stages, those configurations were evaluated for resulting spray material deposition and coverage within the canopies as well as it's the drift potential. Optimal SSCDS configurations suitable for vineyards and apple orchards will be further tested in upcoming 2018-19 season. Team is also working on next generation proof-of-concept reservoir delivery system that can be integrated with standard SSCDS for semi-automated chemical applications.

Selected Research Project Summaries

Steam-generated HMO based Thermotherapy as an Immediate Treatment for Prolonging Productivity of HLB-infected Citrus Trees

Funding Agency: U of Florida, USDA-NIFA SCRI
WSU Investigators: Lav Khot and Gwen Hoheisel

There are currently no means of treating huanglongbin (HLB) or greening infected citrus trees and immediate action is needed to manage HLB-infected orchard blocks. This project therefore investigates the biological, engineering, and economic aspects of the steam based thermotherapy technique for HLB management. WSU team's efforts are towards development of horticultural oils based application techniques for tree canopy pre- and post-treatment to improve effectiveness of the thermotherapy. Team is also leveraging such efforts to develop and evaluate thermotherapy treatments in combination with the horticultural oils mixtures towards the effective management of pear psyllid outbreak during various production stages in the WA State and investigating effectiveness of thermotherapy in pear decline disease management.

Unmanned Aerial Systems (UASs) for Mitigating Bird Damage in Blueberry

Funding Agency: WSU Emerging Research Issues Grant
WSU Investigators: Manoj Karkee, Matthew Taylor and Qin Zhang

Every year, significant fruit yield loss is attributed to bird damage in WA and other parts of the country in various types of fruit crops. The issue is particularly prevalent to Washington and Oregon vineyards but is also a critical issue for cherries and other fruits including blueberries and raspberries. Washington State grape, blueberry, cherry, and Honeycrisp apple farmers lose $80 million annually to bird damage. Netting, auditory scare devices, visual scare devices, chemical applications, and active methods such as trapping, falconry, and lethal shooting are the most common ways that bird control is practiced. However, netting is the only method viewed by most farmers as effective, which also is costly and lethal to a host of wildlife. In this work, we are investigating the efficacy of using multi-rotor and fixed wing Unmanned Aerial Systems (UASs) to deter birds from vineyards and blueberry fields. After showing that human-guided UASs can effectively deter birds, we are working on applying machine learning techniques to autonomously deter birds out of an area.

Books and Book Chapters

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Invention Disclosures

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Commercialization

The FairWeighTM System

Researchers Who Supported the Process: Matthew Whiting

We have supported commercialization of a field-portable system that permits growers to reimburse pickers on a weight basis (rather than the current piece-rate pay system), collects informative data on harvest, and facilitates input of harvest data into payroll software. The FairWeighTM system keeps records of each picker's productivity, weighing the fruit they harvest over time. This system can improve the accuracy of picker reimbursement, fruit handling logistics, and decision making in the orchard. **Contact:** http://fairweighs.com

One of the early prototypes

prototype #1 of thinning end effector

The Bloom Bandit

Researchers Who Supported the Process: Karen Lewis

We have supported the commercialization of The Bloom Bandit which is manufactured by Automated Ag Systems in Moses Lake, WA. This hand held thinner is used to thin blossoms in apple, sweet cherry and stone fruit trees. The hand held thinner was designed based on work completed at WSU CPAAS and the application or use in orchards is guided by the field trials conducted by WSU Extension affiliated with the center.

The first units became available in March 2014. As of Dec 31, 2015 - 98 units have been sold in the USA, New Zealand and South Africa. **Contact**: http://automatedag.com/

Significant Research and Development Accomplishments to Date

Smart sprayer

WSU Investigators: Francis J. Pierce, Feng Kang, Patrick Scharf, Qin Zhang

This device was developed for practicing barrier application for cutworm control and chemical control of suckers in vineyards and high-density tree fruit orchards. It uses a target recognition system to detect plant trunks, and controls a multi-nozzle spraying system rapidly and precisely applying chemicals to obtain an adequate coverage on plant trunks. Spray efficiency tests showed that targeted applications applied higher application densities at <10% of the spray volume compared to that with commercial applications with about 65-70% of the spray hitting the target under the environmental conditions tested. The trailer targeted sprayer for cutworm control performed well and would greatly reduce insecticide application costs and open up opportunities for alternative control products that are more desirable but prohibitively expensive in larger application volumes used in conventional application systems.

Contact: Qin Zhang (qinzhang @wsu.edu, or 509-786-9360) if interested in adopting or transferring this technology.

Labor Management System

WSU Investigators: Matthew Whiting, Yiannis Amatpadis, Li Tan

We have developed a real-time labor monitoring system with the ability to track and record individual picker rate/productivity during manual harvest of specialty crops. This system utilizes existing commercial harvest equipment and integrates a digital weighing scale, RFID reader, computational unit, and cloud-based software for visualization. As fruit is dumped into a standard collection bin, the system can read simultaneously a picker's ID (RFID tag) and measure the weight of fruit. This system shows potential to improve the accuracy of picker reimbursement, fruit handling logistics, and decision making in the orchard.

Contact: Matt Whiting (mdwhiting@wsu.edu)

Significant Research and Development Accomplishments to Date

Precision, site-specific irrigation control of an apple orchard

WSU Investigators: Troy Peters, Yasin Osroosh, Qin Zhang

This allows for site-specific and individual automatic control of various areas of an orchard. Various types of data is collected from each sub-plot within the block including soil moisture, air temperature, and canopy temperature. This data is reported back to a central control computer which analyzes the data, makes irrigation decisions, then automatically opens and closes irrigation control solenoid valves to optimally manage the irrigation for each sub-plot within the block. This setup is currently being used to test various irrigation automation algorithms.

Contact: Troy Peters (troy_peters@wsu.edu, or 509-786-9247) if interested in adopting or transferring this technology.

Hand-Held Fruit Trees Mechanical Blossom Thinner

WSU Investigators: Qin Zhang, Karen Lewis, Meng Wang

This device can be used to thin fruit tree blossom of, including but not limited to Cherry, Apple, Pear and Apricot with minor modification of the thinning head configuration. It improves thinning efficiency, reduces labor cost and improves fruit quality illustrated by trials conducted in orchards in Washington, Oregon, Pennsylvania in US, as well in Chile.

Contact: Qin Zhang (qinzhang @wsu.edu, or 509-786-9360) if interested in adopting or transferring this technology.

Knot-Tying Robotic End-effecter for High-Trellis Top Twining

WSU Investigators: Qin Zhang, Long He, Henry Charvet

Twining is a labor intense task in high-trellis hop production. This robotic knot-tying end-effector was developed to perform automatic knot-tying. Concept validation tests proved that the invented knot-tying end-effector could successfully tie clove hitch knots satisfactorily on trellis wires.

Note: This technology was developed under private funding support, and is not available for technology transfer.

A Remotely Controlled Bin-dog for In-orchard Bin Handling

WSU Investigators: Qin Zhang, Long He, Yunxiang Ye, Karen Lewis

This is a remotely controllable self-propelled bin handling platform implementable in typical Washington tree fruit orchards. It is capable of traveling in typical WA/OR tree fruit orchards; and (2) capable of placing an empty bin at target locations in the row to support efficient picking and transporting a full bin to the designated bin landing area. The developed prototype- could accomplish the designated functionalities based on the tested results in both off-field environment and orchard environment in 2012 harvest season.