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University Council

October 6, 2017

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Dear Colleagues:

The attached proposal from the Office of Research for a new Phenomics and Plant Robotics Center will be an agenda item for the October 13, 2017, Full University Curriculum Committee meeting.

Sincerely,

Alison F. Alexander, Chair
University Curriculum Committee

cc: Provost Pamela S. Whitten
Dr. Rahul Shrivastav

Proposal for a New Center

Phenomics and Plant Robotics Center

Proposed by:

Changying Li

09/14/17

Changying Li, Director

Date

Phenomics and Plant Robotics Center

Approved by:

David Lee

09/14/17

David Lee

Date

Vice President for Research

Table of Contents

1. Name	2
2. Mission	2
3. Context	2
4. Center goals, specific outcomes, and measures of success	4
5. Added value of the new Center	5
6. Research foci and areas of expertise	7
7. Organizational structure and operating procedures	8
8. Facilities and staffing needed for initial operations	10
9. Budget	10
10. Program review	11
11. Appendix A: Potential faculty members and their expertise	12
12. Appendix B: Letters of Support	13

1. Name

Phenomics and Plant Robotics Center (P2RC)

2. Mission

The long-term mission of the Center is to address a major grand challenge facing humanity: to feed and sustain a growing human population amidst increasing climate variability and less arable land. The Center fosters and supports: (1) interdisciplinary collaboration and convergence between plant breeding/genomics, plant biomass characterization, engineering, and computational sciences to propel UGA into a global leadership position in phenomics and plant robotics; (2) education and training to provide interdisciplinary experiences that target the need for cross-trained scientists at the interface of plant science and technology; and (3) outreach and partnership building between academia and industry to accelerate technology adoption.

3. Context

The global human population is projected to exceed 9 billion by mid-century¹. To meet the demand for food, feed, fiber, and fuel, agricultural production must double. It is unlikely that arable land will be increased appreciably in the future due to accelerating losses from urbanization, salinization, and desertification². Further, global climate change will make it harder to grow agricultural crops in many parts of the world. Crop yield could drop by 30-40% at higher temperatures². Climate change will also bring new precipitation patterns in many parts of the world. Fresh water for irrigation is also under threat from overuse and climate change induced by humans.

The genomics revolution provides unprecedented power to develop new and advanced crop cultivars with the gene combinations needed to support the rapidly increasing world population while adapting to the changing climate, e.g., through drought, salinity, and disease/pest resistance³. Genomic information can now be obtained relatively quickly and inexpensively for thousands of genotypes in plant breeding and selection programs. But relating these molecular signatures to key differences in phenotype (such as plant or root architecture, yield, biomass quality, and stress or biotic resistance) remains laborious, expensive, and imprecise, requiring manual assessment of one plant at a time for traits that may be difficult to score visually. As such, *rapid and reproducible measurement of crop phenotypic parameters is a major bottleneck in plant genomics research and breeding programs.*

High-throughput phenotyping (HTP) technologies that can acquire important traits at high spatio-temporal resolutions will form an essential part of a new “Green Revolution” to further improve crop yield and quality as well as to understand the genetic basis of complex traits. Robotics and advanced imaging technologies offer the potential to acquire fine-scale information about plant growth, development and biomass quality, with more and improved measurements of plant growth responses permitting these growth changes to be related to environmental phenomena such as

¹ Roberts, L., *9 Billion?* Science, 2011. **333**(6042): p. 540-543.

² Godfray, H.C.J., et al., *Food security: the challenge of feeding 9 billion people.* Science, 2010. **327**(5967): p. 812-818.

³ Rahaman, M.M., et al., *Advanced phenotyping and phenotype data analysis for the study of plant growth and development.* Frontiers in Plant Science, 2015. **6**.

diurnal changes in temperature and humidity, as well as episodic events such as rainfall or irrigation. Iterative measurements of growth responses over entire seasons may permit scientists to obtain not merely an end-point measurement but to unmask complex series of underlying individual responses that can inform a new level and quality of decision-making in selection of crop genotypes for specific production conditions. Another challenge and opportunity for season-long image-centric plant phenotyping is how to efficiently manage the resulting big datasets (in Petabyte scale over a year) and develop robust data mining pipelines and computational platforms.

Among the ten big research ideas identified by the NSF in 2016 for future investments ⁴, four are closely related to activities within the proposed Center:

- 1) Understanding the rules of life: predicting phenotypes from genotypes;
- 2) Human-technology frontier (i.e., robotics and virtual reality);
- 3) Harnessing data for 21st century science and engineering; and
- 4) Growing convergent research.

As stated in the NSF report ⁴, “the grand challenges of today ... will not be solved by one discipline alone. They require convergence: the merging of ideas, approaches and technologies from widely diverse fields of knowledge to stimulate innovation and discovery.” With exactly this spirit, the Phenomics and Plant Robotics Center will integrate relevant disciplines across campus to tackle this grand challenge.

Education and workforce development is another important mission of the Center. The demand for employees with big data expertise has risen sharply across all sectors of the U.S. economy. According to a recent Forbes Tech report, demand for many data science positions is expected to increase by between 80 and 90% over the next year ⁵. As a result, formal degree or certificate programs in data science have skyrocketed, primarily in areas related to business, consumer, and health care analytics. In contrast, there are currently no specialized training programs in agricultural data analytics, providing an opportunity for UGA to position itself at the leading edge of this emerging field. Indeed, agriculture is viewed by many as the “next frontier” in big data generation and analysis, especially when considering data-intensive applications such as plant phenomics, precision agriculture, climate and weather-based modeling, crop and livestock imaging and sensing, produce tracking and supply chain logistics, and food consumer analytics, among others. Multinational companies such as IBM, Monsanto, and DuPont Pioneer have recognized this opportunity and are investing heavily into agricultural big data and associated analytics platforms. Also of note, venture capital investment into agricultural technologies in the U.S. has nearly doubled each year since 2012 to reach an estimated total of \$4.1 billion in 2015 ⁶; the top four areas of investments are all in data-intensive subsectors such as drones and robotics, food e-commerce, precision irrigation, and decision support technology. As a result, one important goal of the Center is to provide training to the next generation “data-smart” students working in phenomics and plant robotics.

⁴ NSF. 10 Big Ideas for Future NSF Investments.

https://www.nsf.gov/about/congress/reports/nsf_big_ideas.pdf.

⁵ Columbus, L. 2014. Where big data jobs will be in 2015. Forbes Tech 29 Dec. 2014.

⁶ AgFunder. 2015. AgTech Investing Report. Mid Year Report 2015. AgFunder, New York, NY.

4. Center goals, specific outcomes, and measures of success

The long-term goals of the P2RC are to propel UGA into a global leadership position in the high-impact area of phenomics and plant robotics and to provide interdisciplinary educational programs to train the next generation scientists and workforce. The P2RC will leverage UGA's world-class plant sciences portfolio (e.g., Plant Center, Complex Carbohydrate Research Center (CCRC)), as well as plant robotics/sensing, and the new Georgia Informatics Institutes (GIIs) to create a nucleus for interdisciplinary collaboration and convergence of sciences. The sciences that the Center will champion are plant genomics and engineering science (in particular robotics and computational science). The fundamental goal of the Center is to develop robotics technologies to accelerate the application of genome information in the improvement of plants that produce food, fuel, feed, and fiber. As such, the P2RC will accelerate fundamental and applied plant science with breakthrough developments in engineering and computational sciences as well as enable UGA to attack scientific questions that cannot be carried out at other institutions that lack close integration of plant and engineering sciences. The P2RC will enhance our visibility and create new opportunities for extramural funding from private and federal sources. It will also seek to establish international collaborations with phenomics centers in Europe, Australia, and Asia.

Figure 1, a three-plane diagram modeled after the process used by the NSF Engineering Research Center (NSF-ERC), illustrates the fundamental knowledge base and enabling technologies necessary to invoke changes at the systems level. At the top level, we hope to develop three systems (ground, underground, and aerial systems) through technology integration for field-based HTP to achieve predicting phenotypes from genotypes. The technology base includes: unmanned ground/aerial robots, deep learning, multiscale modeling, new sensing technologies such as terahertz imaging and x-ray fluorescence imaging for root sensing, and genetic analysis tools such as GWAS and QTL. At the fundamental level, the knowledge base includes: plant genetics and genomics, plant breeding, plant physiology, plant biochemistry and chemistry, bioinformatics, artificial intelligence, robotics science, statistics, geospatial sciences, and optics.

Specific outcomes and measures of success can be assessed by the criteria listed in Section 11.

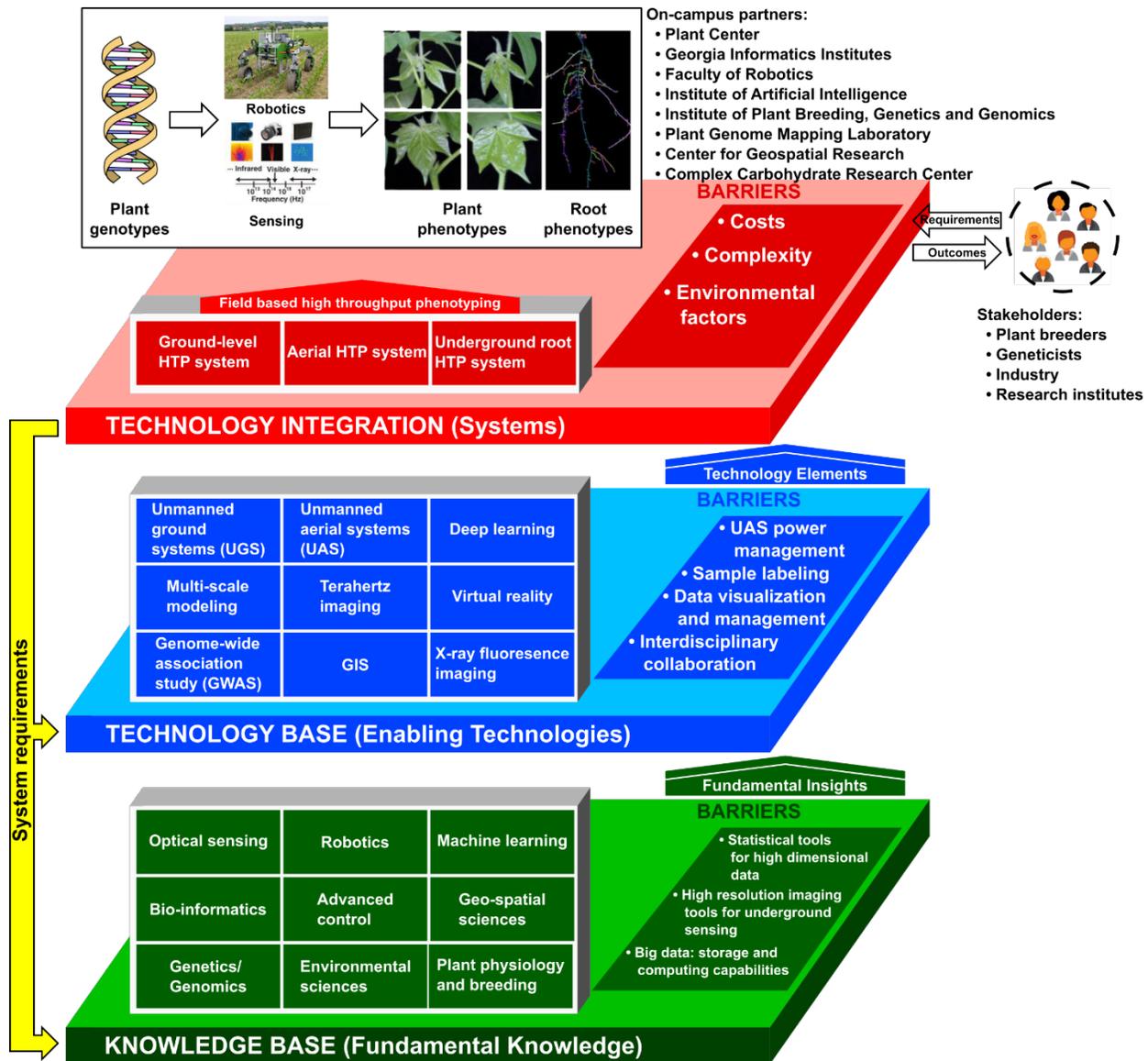


Figure 1. Three-plane diagram illustrating the fundamental knowledge base and enabling technologies necessary to invoke changes at the systems level for the Phenomics and Plant Robotics Center.

5. Added value of the new Center

UGA has traditional strengths in world-class plant sciences, in particular plant breeding, genomics and genetics, and plant biomass (cell wall) analysis. In addition, the College of Engineering, the fastest-growing college at UGA, is building its strengths rapidly in engineering sciences. *No currently existing UGA academic units, however, can provide a platform to integrate these strengths with a focused effort in the emerging area of phenomics and plant robotics, nor can they provide educational programs for those students working at the interface of plant science and engineering/data sciences.* Phenomics is highly interdisciplinary and complex, and progress

cannot be achieved by a single lab or an academic unit. For example, predicting phenotypes from genotypes requires not only sequencing the plant genome and measuring various phenotypic traits in high-throughput using robotics and advanced sensing technologies, but also analyzing data at the terabyte scale using image processing and artificial intelligence, multi-scale modeling, geospatial analyses, and new statistical tools to establish the necessary associations.

Building upon UGA's traditional strengths in the plant sciences, as well as growing strengths in plant robotics/sensing, and the Georgia Informatics Institutes (GIIs), the Center will create the necessary nucleus for interdisciplinary collaboration and convergence between the plant genomics and engineering sciences. In addition, the Center will also coordinate with the Center of Cyber-Physical Systems that is currently under planning in the College of Engineering to avoid duplication of effort and achieve synergies between the two units. The P2RC will enhance our visibility and create new opportunities for extramural funding from private and federal sources.

The following academic units across the UGA campus have been involved in planning the P2RC by contributing core faculty and will benefit from the integrative and strategic activities of the Center. Their leaders have provided letters of support.

- College of Engineering
 - School of Electrical and Computer Engineering
 - School of Chemical, Materials and Biomedical Engineering
 - School of Environmental, Civil, Agricultural and Mechanical Engineering
- College of Agricultural and Environmental Sciences
 - Department of Crop and Soil Sciences
 - Department of Plant Pathology
 - Department of Horticulture
- Franklin College of Arts and Sciences
 - Department of Plant Biology
 - Department of Genetics
 - Department of Statistics
 - Department of Computer Science
 - Department of Mathematics
 - Department of Biochemistry
- Warnell School of Forestry and Natural Resources
- Plant Center
- Institute of Plant Breeding, Genomics and Genetics (IPBGG)
- Georgia Informatics Institutes (GIIs)
- Institute of Bioinformatics (IOB)
- Complex Carbohydrate Research Center (CCRC)
- Plant Genome Mapping Laboratory

Value added by the Center includes a Phenomics and Plant Robotics Symposium or Faculty Retreat on an annual basis. The purpose of the Symposium/Retreat is to critically review the state-of-the-art, identify research gaps, and build a network of collaborators and stakeholders. We will invite thought leaders around the world and program officers from relevant funding agencies, as well as industry representatives to give presentations and facilitate group discussion. The Center

on the UGA campus interested in phenomics together, inform team members on the ongoing research, and develop a shared vision. The Center will hold proposal development workshops to bring key project personnel together for a one-day face-to-face meeting to initiate the process of outlining and writing a full proposal for the targeted grants. In addition, as the Center further grows, core facilities and equipment in high throughput phenotyping could be developed and shared to benefit all faculty on campus.

More importantly, the Center serves as an outward-facing unit beyond the campus. This name recognition is critical to letting federal agencies, potential collaborators in partner institutions, and future students readily identify the campus-wide efforts in phenomics and plant robotics. Establishment of and initial investment into the Center demonstrates the commitment from the university and showcases a campus-wide concerted effort in one particular area, which is key for winning large center-like grants such as the NSF Engineering Research Center. Funding agencies nowadays rarely award large research center grants to institutions that have not shown ongoing concerted research activities. As phenomics is an emerging field addressing grand challenges, UGA will be disadvantaged and miss out on many opportunities to pursue large grants without an integrated Phenomics and Plant Robotics Center.

The Center will develop partnerships with other institutions in the areas of phenomics and plant robotics around the nation and world. These partnerships will be critical for the Center to compete for external funding and enhance our national and global visibility. Currently, the founding members of the Center (Bucksch, Jackson, Li, Ma, and Scherm) have developed or are actively developing collaborative relationships with academic partners at:

- Penn State University
- Purdue: North America Phenome Center
- University of Nebraska – Lincoln
- Iowa State University
- Washington State University: Center for Precision & Automated Agriculture Systems (CPAAS)
- European Phenome Center
- Australian Plant Phenomics Facility
- China Phenome Center (under development, led by Nanjing Agricultural University)
- Mahidol University, Thailand
- Finnish Geospatial Research Institute FGI and Centre of Excellence in Laser Scanning Research, Finland

6. Research foci and areas of expertise

Faculty members of the Center are from 5 different colleges and 10 departments/schools at UGA. They provide considerable cross-disciplinary expertise. During the development of the proposal, these members identified the following research themes and areas that synergize existing strengths and align with emerging research opportunities:

- Robotics and sensing

- Unmanned aerial systems
- Unmanned ground vehicles
- Advanced robotic control
- Virtual reality/augmented reality
- Cyber-physical systems
- Internet of Things
- Spectroscopy and imaging (X-ray fluorescence imaging, Terahertz imaging)
- Geospatial sciences (GIS, GPS, and remote sensing)
- Glycome profiling
- Big data analytics
 - Machine learning
 - Multivariate data analysis and new statistical tools
- Genotype to phenotype association
 - G x E analysis
 - Genome-wide association study (GWAS), quantitative trait loci (QTL) mapping
 - Predict phenotypes from genotypes
- Shoot (above-ground) and root (underground) phenotyping and chemotyping for row crops and specialty crops
 - Organismal level: plant height, crown size, volume, canopy morphological structure
 - Organ level: branching pattern, flowering progression, leaf orientation, organ position mapping and quantification
 - Anatomical level
- Abiotic and biotic stress phenotyping
 - Drought tolerance, flood tolerance
 - Pathogen resistance
- Multi-scale modeling
 - Molecular level (gene regulation and networks, carbohydrate structure of biomass), cellular level (metabolism), tissue level (tissue growth), organ level (organ growth), whole-plant level (phenology), crop level (yield), and ecosystem level (carbon flux)

7. Organizational structure and operating procedures

The Center will be housed in the Office of Research. The P2RC organizational chart (Figure 2) represents the general framework that defines the leadership structure and operation procedures of the Center.

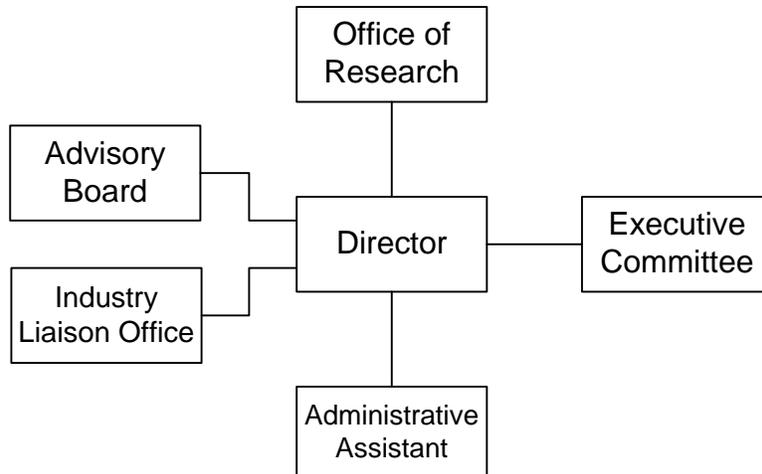


Figure 2. Organizational structure of the Phenomics and Plant Robotics Center.

The **Director** is the chief administrative office of the Center. The Executive Committee will administer a vote of P2RC members for the position of Director. Based on the vote, the Executive Committee will make a recommendation to the Vice President for Research, who appoints the Director. The Director will serve a 5-year term, will be assigned appropriate administrative time to fulfill the duties associated with the position, and will report administratively to the Vice President for Research. The Director may be reappointed. The Director is responsible for providing both scholarly and administrative leadership for the Center. The Director chairs the External Advisory Board as well as the Executive Committee and is responsible for establishing the leadership team as the Center starts and matures. The founding Director of the Center is Changying “Charlie” Li, Professor of Engineering.

An **Executive Committee** will be responsible for establishing policy for the Center and advising the Director on priorities for research and education activities based on input solicited from all faculty affiliated with the Center. The Executive Committee will also evaluate faculty applications for Center membership. The Executive Committee consists of at least five faculty members broadly representing the diverse academic units participating in the Center. The committee is convened and chaired by the Director.

The **Advisory Board** will be comprised of outside experts from other academic institutions or industry partners, to be selected by the Center leadership team. The board will provide advice on strategic research directions and progress towards goals and make recommendations regarding any needed course corrections. The board must meet as a group at least once a year, convened by a chair who organizes the board’s activities in coordination with the director. Administrators from the participating colleges (CENGR, CAES, Franklin, and Warnell) will serve as ex officio members of the Advisory Board.

Administrative assistance will be provided to the Center by an Office of Research team to assist in coordinating meetings and conferences (such as symposia, planning meetings for large grants, and curriculum meetings), answering phone calls and email inquiries, and maintaining web and social media presence.

The **Industry Liaison Officer** is a part-time staff member responsible for developing and coordinating industrial involvement and managing the Center's translation of research for potential industrial applications. Dr. Crystal Leach, the UGA Director of Discovery and Innovation Partnerships, will fill this position.

Membership development

UGA faculty members with relevant research interests can apply for affiliation with the Center, whereby applications will be evaluated by the Executive Committee. Participating faculty will maintain their existing appointments in their home academic units. Participating faculty are expected to attend Center meetings and retreats, actively participate in and contribute to Center research and development activities, provide their field of expertise for proposal development and educational programs, and promote the Center to potential sponsors and partners.

8. Facilities and staffing needed for initial operations

The Center will utilize existing facilities and physical resources on campus in consultation with the owners of these facilities. These facilities include the high throughput phenotyping system jointly developed by Charlie Li (CENGR) and Andrew Paterson (CAES/Franklin), the phenotyping fields on the Iron Horse Plant Science Farm and Horticultural Farm, as well as lab resources and greenhouses for plant studies from the participating departments or CAGT. Other existing facilities include computing facilities in CENGR, GRCRC, and equipment purchased through CAES and CENGR seed grants, as well as ongoing Presidential Interdisciplinary Seed Grant and National Robotics Initiative grants.

9. Budget

Part of the Presidential Interdisciplinary Seed Grant (PISG) received by the planning team in 2017 will be used as the startup fund for the Center. The funds will be used to support proposal planning meetings or research symposia to bring together experts in this area both within UGA and around the nation, as well as to develop industry and inter-institutional partnerships.

Administrative assistance will be provided to the Center by an Office of Research team. The Center will be administered under the Office of Research and jointly supported by the four participating colleges: College of Engineering, College of Agricultural and Environmental Sciences, Franklin College of Arts and Sciences, and Warnell School of Forestry and Natural Resources. The operating fund will be used to support travel for proposal development/team building, meeting space fees for symposia/retreat meetings, etc.

The Center will increase externally funded research in the areas of phenomics and plant robotics, from both federal and industry funding sources. Center faculty have been highly successful in competing for large national competitive grants. Successful grants received by the core faculty members within the last 3 years total nearly \$18M, including some of the most competitive national research initiatives, such as NSF-NIFA National Robotics Initiative, NIFA SCRI, NSF-MCB, DOE-ARPA-e, and NIH R-01. Other highly relevant funding sources that the Center will pursue after its formation include:

- NSF National Robotics Initiative (up to \$45M per year) (we have two active projects)
- NSF Plant Genome Research Program (\$15M per year) (W. Parrott and S. Jackson ran this program before)
 - NSF Cyber Physical Systems (\$31M per year) (our CENGR team had successful grants)
 - NSF PFI:BIC Smart Service Systems (\$10M per year) (we have one proposal under review)
- USDA NIFA Specialty Crops Research Initiative (\$46M in FY2017) (we have one active project and multiple successful prior grants led by Scherm and Li)
 - NSF Smart and Autonomous Systems (\$16.5M per year)
 - NSF Industry/University Cooperative Research Centers Program (I/UCRC) (\$1M per year)
 - DOE ARPA-e ROOTS (\$30M in plant phenotyping, A. Bucksch has one active project)
 - USDA NIFA Agriculture and Food Research Initiative (\$350M in FY2017)
 - NSF National Engineering Research Center (\$20M per project for first 5 years)

10. Program review

The Center will undergo an initial review by the end of the third year and all subsequent regularly scheduled reviews (no less frequently than once every 7 years) by the Office of Research to ensure that the Center is fulfilling its mission and stated goals.

During its third year review and subsequent regular reviews, the Center will produce a report summarizing all research and funding efforts, including the scholarly productivity of Center-affiliated faculty. Some of the measurable deliverables include:

- Number of research projects in the Center and level of involvement by Center faculty
- Number of interdisciplinary grants related to phenomics and plant robotics
- Research productivity of core faculty based on indicators of scholarly activity, such as numbers of journal articles published, conference presentations, invited presentations, books and book chapters, reports, software, and other artifacts
- Number of grant and contract proposals submitted
- Number of grant and contract proposals awarded
- Amount of external funding received
- Number of M.S. and Ph.D. students supported
- Number of students participating in educational programs offered by the Center
- Number of partnerships created with industry, domestic and international institutions
- Number of new crop cultivars that are benefited from new technologies

In addition to the above quantitative measures, the following qualitative measures will be assessed during the review process:

- Has the Center become a catalyst for interdisciplinary research?
- Is the Center successfully cultivating and growing a national and international reputation?
- Has the Center met its original milestones or adaptively moved to seize opportunities to establish and achieve new milestones?

11. Appendix A. Potential Faculty Members and Their Expertise

- Alex Bucksch (Assistant Professor, root phenotyping)
- John Burke (Professor, Plant Biology)
- Jason Cantarella (Professor, shapes of random curves and polygons, Department of Mathematics)
- Katrien Devos (Professor, Plant Biology, cereal genetics & comparative genome analysis)
- Lisa Donovan (Distinguished Research Professor, Department Head of Plant Biology, plant evolutionary ecophysiology)
- Prashant Doshi (Professor, Director of Faculty of Robotics)
- Mable Fok (Associate Professor, optics and microwave sensing)
- Michael Hahn (Professor, cell biology and biosynthesis of plant cell walls, CCRC)
- Mark Haidekker (Professor, X-ray imaging, optical tomography)
- Scott Jackson (Georgia Research Alliance Eminent Scholar, Director of Plant Center)
- Pengsheng Ji (Assistant Professor, multivariate data analysis, Department of Statistics)
- Kyle Johnsen (Associate Professor, Director of GII, virtual reality)
- Peter Kner (Associate Professor, Optics and biophotonics)
- Changying Li (Professor, high throughput phenotyping, robotics)
- Tianming Liu (Distinguished Research Professor, biomedical image analysis, Department of Computer Science)
- Ping Ma (Professor, big data analytics, Department of Statistics)
- Marguerite Madden (Professor, Director of Center for Geospatial Research)
- Cecilia McGregor (Associate Professor, watermelon breeding and genetics)
- Javad Mohammadpour (Assistant Professor, co-PI of the NRI project, system dynamics and controls)
- Debra Mohnen (Professor, cell wall structure, function and synthesis, biomass quality and improvement for polymers and carbohydrate-based bioproducts, Department of Biochemistry)
- Cristian Montes (Associate Professor, spatial information technology, GIS, remote sensing, Warnell)
- Peggy Ozias-Akins (Professor, Director of IPBGG)
- Wayne Parrot (Professor, former NSF PO-Plant Genome Initiative, CAGT, CSS, IPBGG)
- Andrew Paterson (Regents Professor in Plant Genome Mapping Laboratory, Department of Genetics (Franklin))
- Shannon Quinn (Assistant Professor, distributed computing, Department of Computer Science)
- Glen Rains (Professor, Department of Entomology)
- Ramaraja Ramasamy (Associate Professor, plant electrochemical biosensors)
- Laksmish Ramaswamy (Professor, large-scale distributed systems, Department of Computer Science)
- Khaled Rasheed (Director of Institute of Artificial Intelligence)
- Harald Scherm (Professor, Department Head of Plant Pathology)
- WenZhan Song (Professor, fog computing and security, sensor networks, cyber-physical systems)

- Esther van der Knaap (Professor, Horticulture, Institute of Plant Breeding, Genetics and Genomics)
- Xianqiao Wang (Assistant Professor, multi-scale modeling, mechanics of hierarchical structures in biological materials)
- Wenxuan Zhong (Associate Professor, big data analytics, Department of Statistics)

12. Appendix B. Letters of Support

Samuel Pardue, Dean of College of Agricultural and Environmental Sciences

Donald Leo, Dean of College of Engineering

Alan Dorsey, Dean of Franklin College of Arts and Sciences

Dale Greene, Dean of Warnell School of Forestry and Natural Resources

Scott Jackson, Director of Plant Center

Kyle Johnsen, Director of GIIs

Peggy Ozias-Atkins, Director of IPBGG

Khaled Rasheed, Director of Institute of Artificial Intelligence

Prashant Doshi, Director of Faculty of Robotics

Marguerite Madden, Director of Center for Geospatial Research

Alan Darvill, Director of Complex Carbohydrate Research Center

Jessica Kissinger, Director of Institute of Bioinformatics

T.N. Sriram, Interim Department Head of Department of Statistics



**UNIVERSITY OF
GEORGIA**

College of Agricultural and Environmental Sciences

Office of the Dean and Director

August 21, 2017

Dr. Changying "Charlie" Li
School of Electrical and Computer Engineering
College of Engineering
712f Boyd Grad Research Ctr.
CAMPUS

Dear Dr. Li,

The College of Agricultural & Environmental Sciences (CAES) supports the Phenomics and Plant Robotics Center (P2RC) proposal developed by you and your colleagues across campus. Plant genetics, genomics, and breeding is one of the internationally recognized areas of excellence in the CAES, and we look forward to leveraging this strength as part of the P2RC to advance robotics, sensing, and high-throughput phenotyping for crop improvement. We are particularly excited about the P2RC's ability to enhance UGA's visibility in this rapidly advancing area and create new opportunities for extramural funding from industry and federal sources such as NSF or USDA-NIFA.

Our college will support our faculty and students involved in this institute and encourage them to participate in workshops, seminars, and grant writing activities. I look forward to working with you and the proposed center. The center can strengthen existing programs and will likely result in new collaborative efforts.

Thank you again for collaborating with CAES scientists on this endeavor, and we look forward to working together to making the P2RC a world-class center in this highly interdisciplinary space.

Sincerely,

Samuel L. Pardue
Dean and Director

SLP/alc

c: Allen Moore
Harald Scherm

July 26, 2017

Changying “Charlie” Li, Ph.D.
Professor
School of Electrical and Computer Engineering
College of Engineering
University of Georgia
200 D.W. Brooks Drive
Athens, GA 30602

Dear Dr. Li:

The College of Engineering at the University of Georgia is pleased to provide strong support for the proposed Phenomics and Plant Robotics Center. This new Center is very timely, and will help to address grand challenges identified by NSF and other mission agencies, building an international reputation in the areas of high throughput phenotyping, robotics, and computational sciences for the University of Georgia. This Center is also strongly consistent with our College’s objectives to grow our research activities in the field of informatics, robotics, cyber-physical systems, and the human-computer interface.

The College of Engineering views the Phenomics and Plant Robotics Center as a potential organizational building block towards an NSF Engineering Research Center in an area that can uniquely leverage UGAs strengths. As a result, our college has significant resources and expertise in these areas that we will make available to participate. In particular, the College of Engineering has front-loaded its support with up-front payment of two years of operating funds (\$10,000 in total) to help you accelerate the early launch of the Center. In addition, the College will work with you to continue during the Center’s startup phase the course release provided over the past two academic years as a result of your research productivity.

We appreciate your leadership in this endeavor and look forward to working together to make the Phenomics and Plant Robotics Center a focal point for our research and educational activities in the high impact area of phenomics and robotics at UGA.

Sincerely,



Donald J. Leo, Ph.D.
Dean
UGA Foundation Professor in Engineering



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Franklin College of Arts and Sciences
Office of the Dean

August 22, 2017

Dr. Changying "Charlie" Li
School of Electrical and Computer Engineering
College of Engineering
University of Georgia

Dear Dr. Li:

I write on behalf of the Franklin College of Arts and Sciences in support of the proposed Phenomics and Plant Robotics Center. This new center will address a grand challenge facing humanity in regard to food security and build the international reputation of the university in the areas of high-throughput phenotyping, robotics, and data science. Furthermore, this center will enable faculty in Franklin College to initiate new research directions, expand collaborations, and seek new funding opportunities.

The college is committed to support our faculty and students who are engaged in phenomics, plant robotics, and related research. I offer my full support to your effort to establish the Phenomics and Plant Robotics Center.

Sincerely,

Alan T. Dorsey
Dean, Franklin College of Arts & Sciences



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Warnell School of Forestry and Natural Resources
Forestry, Fisheries and Wildlife, Natural Resources Management and
Sustainability, Natural Resources Recreation and Tourism

Office of the Dean

180 E Green Street

Athens, Georgia 30602-2152

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www.warnell.uga.edu

August 21, 2017

Dr. Changying "Charlie" Li
School of Electrical and Computer Engineering
College of Engineering
200 D.W. Brooks Drive
Athens, GA 30602

Dear Dr. Li,

The Warnell School of Forestry and Natural Resources is pleased to provide support for the proposed Phenomics and Plant Robotics Center. We recognize that this Center will work to build an international reputation in areas such as phenotyping, robotics, and computational sciences, while creating new opportunities for extramural funding from industry and federal sources.

We appreciate you and your colleagues working on this endeavor and look forward to working together to make the Phenomics and Plant Robotics Center successful in growing research activities in this field at UGA.

Sincerely,

W. Dale Greene
Dean



UNIVERSITY OF
GEORGIA

The Plant Center
2502 Miller Plant Sciences
Athens, Georgia 30602
706-542-1829
plantctr@uga.edu
www.plantcenter.uga.edu

August 21, 2017

Dear Dr. Li,

On behalf of the Plant Center, I endorse your effort for the Phenomics and Plant Robotics Center. This would involve many faculty in the PC as they are involved various aspects of measuring plant features that would be greatly facilitated by this group as they would have immediate access to engineers, data analytics, informatics and other disciplines. PC members already engaged in this intersection of engineering and plant sciences include Drs. Patterson, Bucksch, Scherm and other with funding from DOE, NSF and USDA. A number of PC faculty are involved intimately with the proposed institute which, in full disclosure, includes me.

We are happy to do anything that we can to help promote this P2RC. Please let me know what we can do to help as this moves forward.

Sincerely,

Scott A. Jackson
Georgia Research Alliance Eminent Scholar and Professor
Director, The Plant Center
University of Georgia
111 Riverbend Rd
Athens, GA 30602

sjackson@uga.edu/706.542.4021



**UNIVERSITY OF
GEORGIA**
*Georgia Informatics Institutes
for Research and Education*

July 28th, 2017

Dr. Pamela Whitten
Senior Vice President for Academic Affairs and Provost
University of Georgia
Athens, GA

Dear Dr. Whitten,

The Georgia Informatics Institutes for Research and Education (GII) is pleased to support the proposal by Dr. Charlie Li to establish the Phenomics and Plant Robotics Center. As the proposal indicates, the center would become part of the GII alliance of informatics-related units. Indeed, many of its founding members are already members of the GII, and I am listed as a core faculty member because of my own activity in robotics.

The GII and the new center will work together to promote the overall growth of informatics on campus. I see particular value in hosting joint events, graduate recruitment efforts, and developing innovative curricula. In addition, we will help navigate the potential overlap with the proposed Center for Cyber Physical Systems proposed by Dr. WenZhan Song. These are truly distinct fields of study, with Cyber Physical Systems focusing more on engineering the built environment rather than the natural one. I believe that these two units will benefit from the each other's growth and activities.

In summary, the GII –and I personally– expect the Phenomics and Plant Robotics Center to be a productive and complementary new part of UGA.

Sincerely,

Kyle Johnsen, PhD
Director, Georgia Informatics Institutes
Associate Professor, College of Engineering
University of Georgia
Athens, GA



UNIVERSITY OF
GEORGIA

Institute of Plant Breeding, Genetics & Genomics
College of Agricultural and Environmental Sciences

IPBGG
111 Riverbend Rd
Athens, Georgia 30602
TEL (706) 542-5607 | FAX (706) 583-0881
pbgg@uga.edu
plantbreeding.uga.edu

August 1, 2017

Dear Dr. Li,

As Director of the Institute of Plant Breeding, Genetics & Genomics, I enthusiastically endorse your proposal for a “Phenomics and Plant Robotics Center”. Formation of such a Center would identify UGA as a center of expertise for cross-cutting technologies in engineering, plant sciences, and computational science. Several faculty in the IPBGG already have established collaborations and projects that combine plant genomics and robotics/sensing/high-throughput phenotyping to conduct cutting-edge research, and these interactions would gain visibility with the formation of P2RC and establishment of formal connections with IPBGG. Many IPBGG faculty already are members of The Plant Center and the Institute of Bioinformatics, and recognize the value of Centers and Institutes for synergizing research collaborations and inevitably graduate education.

If formed, close interaction between IPBGG and P2RC is anticipated since each has complementary strengths. P2RC also is envisioned as a vehicle to reinforce engineering as a component of agricultural science. We expect that new opportunities to develop successful extramural funding proposals will emerge as a result of P2RC activities to offer symposia, workshops, a seminar series and ultimately core facilities, and are excited to participate in this proposed venture.

Sincerely,

Peggy Ozias-Akins, Director
Institute of Plant Breeding, Genetics & Genomics



UNIVERSITY OF
GEORGIA

Institute for Artificial Intelligence
111 Boyd Graduate Studies Research Center
200 D.W. Brooks Drive
University of Georgia
Athens, Georgia 30602-7404
TEL 706-542-0881 | FAX 706-542-2966
www.ai.uga.edu

Franklin College of Arts & Sciences
Institute for Artificial Intelligence

August 21, 2017

To Whom It May Concern,

On behalf of the Institute for Artificial Intelligence (IAI) at UGA, I strongly support the establishment of the Phenomics and Plant Robotics Center (P2RC) at UGA. The interdisciplinary nature and stated goals of the proposed center are strongly needed at UGA and the state of Georgia. I expect the new center to have high potential for attracting external funding. Furthermore, I look forward to a fruitful long-term collaboration between the IAI and the new center in many areas including Robotics, Machine Learning and Optimization. I have personally worked with Dr. Charlie Li on collaborative research and he is also a member of the Artificial Intelligence faculty. I have a lot of confidence in the quality of his work and his leadership and vision.

I believe that the proposed center has the potential to be a successful one, and the establishment of such a center is timely. I strongly support its establishment.

Regards,

Khaled Rasheed

Khaled Rasheed
Professor and Director



UNIVERSITY OF GEORGIA

Faculty of Robotics (an OVPR initiative)

Date: August 21, 2017

To whomsoever it concerns,

The Faculty of Robotics is pleased to offer its support to this new interdisciplinary initiative on phenomics and plant robotics. The Faculty of Robotics (<http://robotics.uga.edu>) is an informal collective of diverse faculty spanning 14 departments across 3 Colleges launched in 2012. Its mission is to enhance the University's prominence in the discipline of robotics by serving as a singular hub for research in robotics that brings together interested University faculty and students from a variety of disciplines.

Plant robotics is gaining significant attention as an important component of precision farming. I believe that this new initiative led by Prof. Changying Li will further enhance UGA's research prominence in agricultural and environment sciences, and serve to establish a firm foothold in precision farming. Prof. Li is a core and active member of the Faculty of Robotics conducting important research in the area of plant robotics, and we are glad that he is taking firm steps toward an increased presence of robotics on the UGA campus. I would be glad to discuss further why this initiative is beneficial to UGA at length if needed.

Sincerely,

A handwritten signature in blue ink, appearing to read 'Prashant Doshi'.

Prashant Doshi
Professor of Computer Science
Director, Faculty of Robotics and THINC lab.
Dept. of Computer Science



August 20, 2017

Changying Li, Ph.D.
Professor, Bio-Sensing and Instrumentation Laboratory
College of Engineering
712F Boyd Graduate Studies
200 D. West Brooks Drive
University of Georgia
Athens, Georgia 30602

Dear Dr. Li,

I am writing to express my support for your proposed Phenomics and Plant Robotics Center (P2RC) as a potential core faculty member from the UGA Department of Geography and Director of the Center for Geospatial Research (CGR). My research, along with that of CGR Associate Director, Dr. Sergio Bernardes, and Assistant Research Scientist, Dr. David Cotten, as well as other faculty, staff and students in CGR, is very much in line with the proposed objectives of the P2RC in terms of interdisciplinary collaboration and cross-training at the intersection of geospatial technologies and plant science.

For over 30 years, we have used remote sensing (e.g., aerial and satellite imagery), photogrammetry, geographic information system (GIS) and field-based observations and measurements to study the health and distribution of plants, biophysical plant processes, human/animal/climate impacts on vegetation and agricultural applications of GIScience (www.cgr.uga.edu). More recently, we have been using drone and multispectral sensor technologies to image vegetation and create 2D, 3D and 4D (time series) data sets to conduct spatio-temporal analyses of plant processes, vegetation structure and geographic distributions. In addition to research, CGR is very involved in education and workforce development through our courses, workshops and participation in the NASA DEVELOP Program and professional societies such as the International Society of Photogrammetry and Remote Sensing (ISPRS), American Society of Photogrammetry and Remote Sensing (ASPRS) and the Association of American Geographers (AAG). We also participate in and support the activities of the UGA Small Satellite Research Laboratory (SSRL) where a very talented and interdisciplinary team of undergraduates are currently designing and building two CubeSat nanosatellites with sensors for imaging terrestrial and aquatic Earth phenomena.

Please do not hesitate to contact me for any assistance I may provide. I look forward to working with you and other members of P2RC in the future.

Sincerely,



Marguerite Madden, Ph.D.
Professor and Director, Center for Geospatial Research

Past 2nd Vice President, International Society for Photogrammetry and Remote Sensing (2012-2016)
Past ISPRS Technical Commission President (2008-2012)
Past President, American Society for Photogrammetry and Remote Sensing (2007)



**Complex Carbohydrate
Research Center**
UNIVERSITY OF GEORGIA

September 13, 2017

Dr. Changying “Charlie” Li
Professor
School of Electrical and Computer Engineering
College of Engineering
University of Georgia
200 D.W. Brooks Drive
Athens, GA 30602

Dear Charlie:

The Complex Carbohydrate Research Center (CCRC) strongly supports the proposed Phenomics and Plant Robotics Center (P2RC). This new Center is very timely, and will help tackle the grand challenge of predicting phenotypes from genotypes and will build an international reputation in the areas of high throughput phenotyping, robotics, and data science at the University of Georgia. Several of the CCRC faculty members are excited about potential collaborative opportunities the new Center will bring to the CCRC.

The CCRC appreciates the opportunity to be involved in interacting with the P2RC. Please let either of us know what else we can do to help make the P2RC successful.

Sincerely,

Alan Darvill
Director and Regents Professor

Debra Mohnen
Professor of Biochemistry and Molecular Biology



UNIVERSITY
GEORGIA

Center for Tropical & Emerging Global Diseases

Institute of Bioinformatics

Department of Genetics

500 D.W. Brooks Drive, Suite 107

Athens, Georgia 30602

TEL 706-542-6562

jkissing@uga.edu

<http://mango.ctegd.uga.edu/~jkissingLab>

September 14, 2017

Dr. Chagyng “Charlie” Li
Professor
School of Electrical and Computer Engineering
College of Engineering
University of Georgia
200 D. W. Brooks Drive
Athens, GA 30602

Dear Charlie,

The Institute of Bioinformatics (IOB) strongly supports the proposed Phenomics and Plant Robotics Center (P2RC). This new Center will provide new data types that are of great interest to many faculty that are shared between P2RC and IOB thus helping to complement the types of research our investigators are able to conduct. Several IOB faculty are excited about the many potential collaborative opportunities that the P2RC will bring.

The IOB greatly appreciates the opportunity to be involved in interacting with the P2RC. Please don't hesitate to involve the IOB in the solution to the data challenges that emerge, we are pretty good with non-sequence data as well. We look forward to helping the P2RC be successful.

Sincerely,

Jessica Kissinger, Ph.D.
Professor of Genetics
Director, Institute of Bioinformatics
Center for Tropical and Emerging Global Diseases



UNIVERSITY OF
GEORGIA

Franklin College of Arts and Sciences
Department of Statistics

July 29, 2017

Dr. Changying Li
College of Engineering
University of Georgia

Dear Dr. Li,

On behalf of the Department of Statistics at UGA, I strongly support the creation of the **Phenomics and Plant Robotics Center (PPRC)** at the University of Georgia. Your proposed institute has great potential to build new interdisciplinary collaborations between various disciplines at UGA. We will be glad to encourage and support our faculty and students to participate in the activities organized by PPRC.

I understand from your proposal that High-throughput phenotyping (HTP) technologies, which can acquire important traits at high spatiotemporal resolutions, will form an essential part of a new 'Green Revolution' to further improve crop yield and quality as well as to understand crop genomics. It is fascinating to learn that Robotics and advanced imaging technologies offer the potential to acquire fine-scale information about plant growth and development with more and improved measurements of plant growth responses, permitting these growth changes to be related to environmental phenomena such as diurnal changes in temperature and humidity, as well as episodic events such as rainfall or irrigation. I also understand that with foundations rooted in statistical methods, big data analytics play a crucial role in analyzing the resulting big datasets from season-long image-centric plant HTP. As you know, the Department of Statistics has strong statistics and data analytics research and education programs, and our faculty and students are also involved in developing fundamental statistical methodologies and algorithms that are useful in various HTP applications. We also believe that there will be ample opportunities to develop new statistical methodologies to tackle problems in the big data and HTP regime.

I am also pleased to learn that three statistics faculty members, Drs. Pengsheng Ji, Ping Ma and Wenxuan Zhong, are already collaborating with you in this important research direction and will participate as core faculty of PPRC. Over the past three years, Drs. Ma and Zhong have established diverse extramurally funded research programs to overcome the computational and

theoretical challenges arising in big data analysis. We hope that this research institute will also provide opportunities for several other faculty and students of Statistics to obtain and contribute knowledge on plant HTP and its impact on statistics and analytics.

We would like to reiterate our full support for the creation of the Phenomics and Plant Robotics Center at UGA. We are optimistic that PPRI will succeed in building new interdisciplinary collaborations, which will benefit a variety of units at UGA.

Sincerely,



T. N. Sriram
Professor and Interim Head
Department of Statistics
University of Georgia



The University of Georgia

Plant Genome Mapping Laboratory

27 Sept 2017

To: Professor Changying Li, College of Engineering
From: Andrew H. Paterson,
Regents Professor and Head, Plant Genome Mapping Laboratory
University of Georgia

Dear Charlie,

This letter is to confirm my support for the proposed Phenomics and Plant Robotics Center. As you know, for the past several years your group and mine have worked closely in this area, publishing several papers and obtaining a significant extramural grant with others pending. I anticipate that we will continue to progress together in this area, toward goals salient to the new Center. While my indirect cost returns were allocated to several UGA units many years ago and are not available for further division, I look forward to continuing to work together on these goals, and to seeking new extramural funding toward areas salient to the new Center.

Sincerely,

Andrew H. Paterson
Regents Professor and Head,
Plant Genome Mapping Laboratory