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Space Administration

tech bytes

AMES' EMERGING TECHNOLOGIES

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Mapping Vascular Patterning for Astronaut Health and Terrestrial Diseases

In this issue:

Chief Technologist's Corner

The coming months will see a lot of activity with respect to innovation. I want to take this opportunity to share information about some upcoming developments.

Collaborations

Ames will soon welcome the United States Geological Service (USGS) to the NASA Research Park. Center management believes that the co-location will underscore that there is real potential for NASA and USGS to pursue scientific research of mutual interest. As a result, this spring the Center will solicit seedling projects to kick start collaborative projects (approximately 5 awards up to $20K). A request for proposals (RFP) will be issued and proposals will be reviewed in accordance with the Internal Research and Development (IRAD) process set up by Offices of the Chief Technologist, Chief Scientist, and Chief Engineer.

Similarly, Ames is interested in encouraging collaboration in selected areas with the Jet Propulsion Laboratory (JPL). The RFP for this year's Center Innovation Fund (CIF) will encourage collaborative proposals with JPL. Expect to see the RFP in the June timeframe.

IRAD

There will be an RFP for Center IRAD this spring. This is a mechanism for Ames to develop strategic capabilities of interest to the Center and/or science/technology projects for targeted opportunities. The goal is to make Ames more competitive, provide opportunities for risk reduction and/or increased cost effectiveness, and initiate potentially transformational solutions to the most challenging mission-related problems.

Workshops

My office will host two "invitation only" workshops this spring. On May 19-20, "Seeking the Tricorder: Workshop on Advanced Technologies for Life Detection" will seek to gather information for the development of an FY18 RFP for low technology-readiness-level (TRL) advanced life detection technologies that can be applied to the surface and near-subsurface of Mars, and ocean worlds dominated by icy terrain. Interest in the possibility of life on Mars has always been high, and there's a lot of excitement about the possibility of life on the icy worlds as well. The second workshop, "Machine Learning from Current NASA Applications to Strategic Vision," will bring together scientists and technologists from Ames, Silicon Valley, universities, and other NASA Centers. The April 11-13 workshop will provide an understanding to domain scientists of what machine learning can do now, explore NASA's role in advancing machine learning to solve Agency problems, and consider how NASA can engage with academia, industry, and others in advancing machine learning.

Breaking Down Stovepipes

Finally, I would like to continue to attack the stovepipes at Ames that hinder communication between disciplines. I believe that we are not good at letting other parts of the Ames family know what we're working on; this hinders our ability to identify technology solutions to pressing problems, and that in turn holds the Center back. So this fall, the Chief Scientist and I plan to host a poster sessions and lightning talks to which the entire Center will be invited. We will probably start by focusing on past CIF and Science Innovation Fund (SIF) projects that we believe are of general interest and might inspire internal collaborations and possibly new innovation.

- Harry Partridge

ABOUT THE COVER

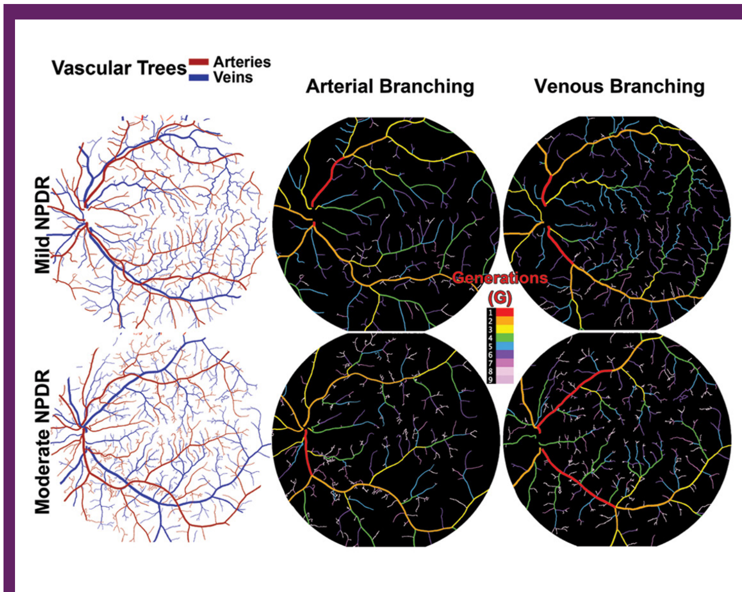
Image of lymphatic vessels growing and expanding around a large blood vessel by recruitment of vascular precursor cells. Photo by Patricia Parsons-Wingerter.

VESGEN Software Awarded Second Consecutive Technology Transfer and Center Innovation Awards

All higher terrestrial organisms, including humans, other vertebrates, insects and even higher land plants, require complex, fractally branching vascular systems for survival. Many progressive human pathologies, such as cancer, coronary vessel disease, diabetes and some reproductive disorders, are dependent upon microvascular remodeling and the formation or destruction of smaller blood vessels. The role of vascular response and function in the health challenges facing astronauts in the microgravity and high radiation environments during long-duration missions to the Moon and Mars are actively investigated by NASA's Human Research Program. Exploration risks that may involve vascular response and remodeling include visual and ocular impairments, accelerated bone loss, cancer, depressed immune response, and muscle atrophy.

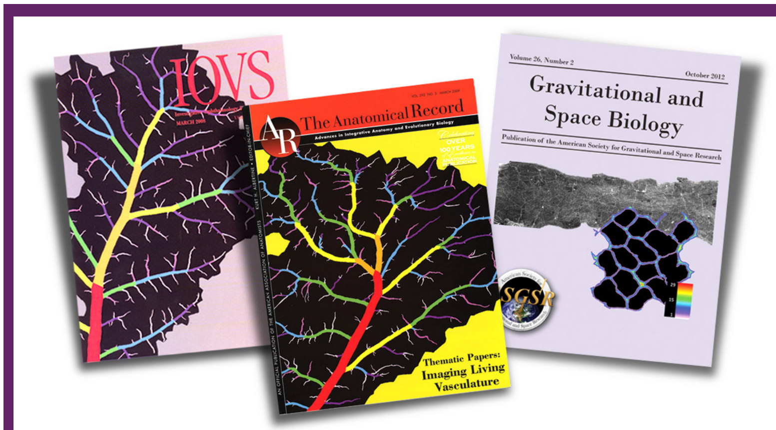
NASA's VESsel GENeration Analysis (VESGEN) software has been developed since 2005 to map and quantify vascular patterning using fractal-based physiological branching rules to help transform our understanding of vascular-dependent disease. Currently the VESGEN 2D software is analyzing human and vertebrate vascular branching for biomedical applications from astronaut exploration health challenges to terrestrial disease. The software is being applied to studies in rodents and the retinas of US crew members before and after missions to the International Space Station.

Support from Center Innovation Fund (CIF) awards in 2016 and 2017 by the ARC Chief Technologist's Office is helping to achieve the goal of advancing from VESGEN 2D to 3D vascular mapping. The CIF developers include Dr. Patricia Parsons-Wingerter, Dr. David Kao, Dr. Hamed Valizadegan and Dr. Rodney Martin, with continuing collaboration with Mary Vickerman of GRC (Glenn Research Center) Data Systems. The team's progress was highlighted when it won the 2016 Patent Application Award from the Ames Technology Transfer Partnerships Office and Office of the Chief Counsel for "A Bioinformatics System for the Analysis of Vascular Patterning in 3D and 2D as Integrative Bio-



***Mappings and Quantification by VESGEN Software of Vascular Remodeling for Better Understanding of Progression of Visually Impairing and Blinding Human Disease.** Arterial and venous branching trees extracted from clinical photographs of patients diagnosed with diabetic retinopathy, a progressive vascular disease, were mapped and quantified for early mild and moderate nonproliferative retinopathy (NPDR) by the VESGEN software (Invest Opthal Vis Science 51(1):498-507). VESGEN mappings resulted in a surprising discovery of early-stage vessel regeneration that is now supported by a further NIH study on correction of defects in a patient's own stem cells. Diabetic retinopathy is the major blinding disease for working-aged adults. The technology for vascular mapping of the human retina is now being used by NASA's Human Research Program for the study of visual impairments developed at high frequency by astronauts during long-duration missions in microgravity.*

VESGEN (continued)



Cover Illustrations from Journals with Research Publications and Reviews of VESGEN Software. The VESGEN mappings of branching vascular trees (left, center) and a vascular network (right) in several animal models display automated mapping concepts derived from weighted vascular physiological branching rules. For example, branching generations within vascular trees defined by VESGEN analysis (red to magenta) support detailed, site-specific quantification of vascular remodeling and therapeutic interventions.

marker of Complex Molecular and Mechanical Signaling*"* (ARC 17659-1). This is the second consecutive year the technology has been honored with this prestigious award.

Original experimental observations motivating software development showed that key molecular regulators and therapeutics of vascular remodeling in tumors, diabetes and tissue inflammation result in unique 'fingerprint' patterns of vascular response, and suggested that fractal-based computer analysis of vascular remodeling would contribute to the improved understanding of vascular-dependent pathologies and successful development of countermeasures and therapeutics. Because of overlapping ophthalmic imaging challenges common to both astronauts and terrestrial humans, research with the software is also funded by the US National Institutes of Health for diabetic retinopathy, the major blinding disease of working aged adults.

The three fundamental types of fractal-based microvascular geometry mapped and quantified by VESGEN are branching trees, continuously connected networks, and tree-network composites, all presented as software interface analysis options to the user. The weighted repertoire of vascular physiological branching rules used in the VESGEN analysis includes bifurcational branching, vessel tapering, and vessel continuity. Applications documented in 18 journal publications have included progressive vascular remodeling in the human retina, mouse and avian models of the heart, intestinal inflammation with probiotic treatment, and tumor angiogenesis studies. Dr. Parsons-Wingerter reports, "We have received about 160 requests for our mature, beta-level automated VESGEN 2D software from scientists around the world. The vascular analysis software has been requested globally by institutions such as Harvard Medical School, Mayo Clinic, the toxicology department of a major US corporation, the US Environmental Protection Agency (EPA), and ESA partnering countries. One major reason I moved to Ames, the Life Sciences research center of NASA, is to work toward extramural beta testing and release of the software to the worldwide research community". ■

ARC Center Director Dr. Eugene Tu and VESGEN Development Team at 2017 Technology Parternerships Award Ceremony. – Dr. Tu Dr. David Kao, Dr. Patricia Parsons-Wingerter, Dr. Rodney Martin, Dr. Hamed Valizadegan. (Image Credit: Dominic Hart)

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Supersize It!

Space exploration has seen a trend toward miniaturization in the past decade or two. Ames in particular has been pursuing a “bigger bang for the buck” by seeking ways to accomplish scientific goals using smaller platforms such as smallsats and CubeSats. But, not everything can be accomplished with smaller platforms. Larger structures will be essential. That’s where Ben Jenett, Holly Jackson, and their colleagues come in.

Ben is a Phd student at Massachusetts Institute of Technology’s (MIT) Center for Bits and Atoms and a NASA Space Technology Research Fellow working with Ames Research Collaborator (RC) Dr. Kenny Cheung. He wants to develop tools that would enable construction of large structures in space that are also reconfigurable and reusable. Conceptually, Ben and the team are starting “small” on the ground – e.g., bridges and shelters – and working their way up to large structures in space along with the robots needed to build them.

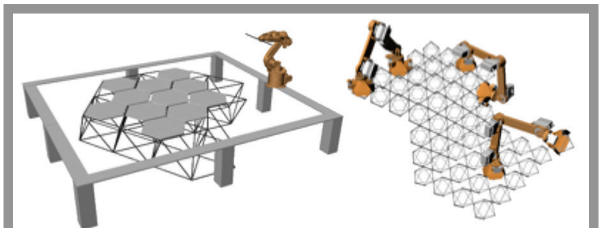

Figure 1: Comparison of robotic assembly platforms for space structures. (left) Traditional motion system with robotic arm, based on work from NASA Langley. (right) Multi-agent relative robotic system (Image Credit: Ben Jenett, 2017)

LEGO-style Approach

Originally, Ben focused his efforts on robotic construction based on in situ resource utilization (ISRU), but his NASA experience prompted him to modify his course slightly. His RC, Dr. Cheung, is pursuing a “LEGO brick” approach to build large structures out of small parts, for applications such as airplane wings. Cheung’s concept is that identical modular elements can be assembled and reassembled in different ways in order to achieve the desired qualities with respect to stiffness, strength, etc.

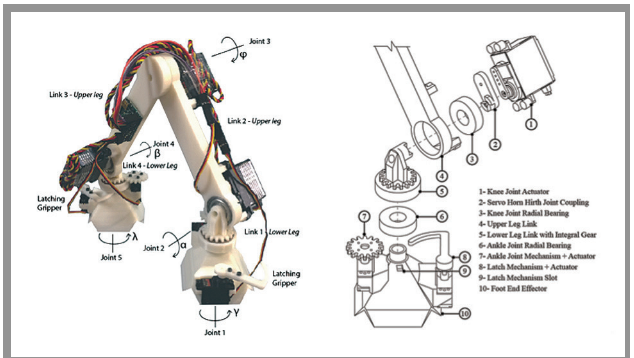

Figure 2: Relative robot Bipedal Isotropic Lattice Locomoting Explorer (BILL-E) (left), building block gripping end effector (right). (Image Credit: Ben Jenett, 2017)

Jenett’s particular contribution is a robot that operates relative to the building block structure. These “relative robots”, deployed individually or in swarms, would be able to manipulate and assemble those modular components. Unlike traditional approaches which build a large structure with an equally large machine, these robots live on the structure, allowing the construction of arbitrarily large structures.

Unique to the LEGO-brick system, known as “digital materials”, is the adaptability to varying mission requirements with the same kit of parts. As an example, Jenett notes that the same basic modular structure could support a space telescope reflector or an aerobrake. However, even if the basic shape is similar, the requirements of the structures vary considerably. The reflector dish has to be precise and stiff. The aerobrake has to be very strong. The underlying modular elements could easily support either, depending on how they are assembled. Jenett’s robots would assemble the modular LEGO-like blocks in whatever way was necessary to achieve the requirements of the structure.

Jenett points out that one of the most attractive aspects of the modular approach is that parts have a very low mass, and therefore can be launched in highly efficient packing configurations to reduce cost. Reducing the mass of the robot constructors is one of his top objectives.

Supersize It! (continued)

Challenges

Jenett's robots are just beginning to learn to walk, with the goal of performing complex maneuvers without complex controls, by leveraging the structured environment of the lattice to simplify metrology. As a next step, Jenett would like to enable his robot workers to be able to bolt parts together, a feat they so far have only accomplished with much larger non-mobile robots. In addition, he observed that large structures will require swarms of assembly robots. Ensuring that the structure will be assembled optimally and meet the physical requirements will necessitate development of complex algorithms to control the swarms. The end result would be a fully automated construction process for large assemblies.

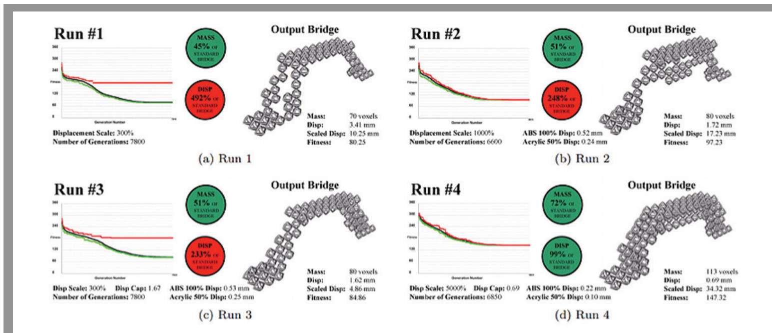

Figure 4: Descriptions of all four bridges optimized by the genetic algorithm and their corresponding optimization parameters. (Image Credit: Holly Jackson, 2016)

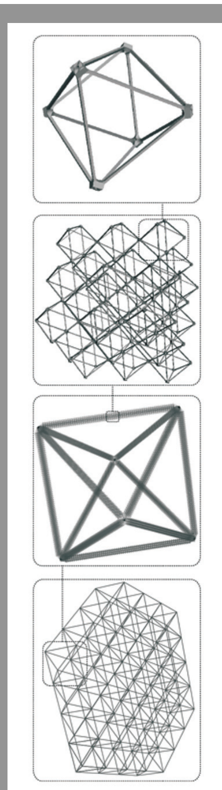

Figure 3: Hierarchical construction of large scale truss structures from building block elements. (Image Credit: Ben Jenett and Christina Gregg, 2017)

Algorithms

Holly Jackson, a junior at Notre Dame High School in San Jose, also works at Dr. Cheung's lab. Her objective is to develop the necessary algorithms, starting with optimizing the truss structures that comprise the modular assemblies. She wants to develop mechanisms that determine how best to use materials at hand to build structures meeting the specifications- something that will be critical to long term missions with limited resources.

She is currently using "genetic algorithms" to do so. The process begins with cuboctahedral truss voxels, or "cubocts", to build a virtual solid beam; it then subtracts material from the beam, assesses the results, and rejects or selects alternatives until the lattice is optimized for the desired structural qualities. She initially tested the approach on 3D-printed bridges, and experimentally verified the predictions generated by her algorithm. She is now seeking to expand it to large structures in space.

Supersize It

Jenett, Jackson, Cheung and their colleagues are applying these technologies to large structures for aero and space applications while keeping down the cost and maximizing utility. The complexity of the components of these systems can be very low, but the possible configurations and behaviors can be as numerous and diverse as conventional systems. As noted above, modular components are one key to this. Low mass and reusability – the ability to reconfigure existing modular structures to obtain different qualities – are others.

In the intermediate future, they are thinking in terms of telescopes with apertures well beyond the state of the art, e.g., a 40-meter modular telescope assembly, or perhaps extraterrestrial infrastructure such as surface shelters for astronauts and their supplies

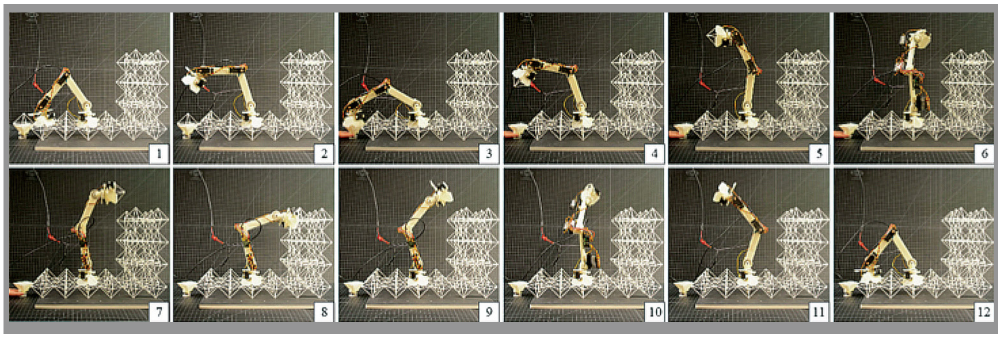

Figure 5: BILL-E performing part gripping and placement in order to build the structure it travels on. (Image Credit: Ben Jenett 2017)

and equipment. But the very same approach could be used to build even larger structures like space stations. In theory, it could also be used to construct super-sized structures: a Stanford torus or Bernal Sphere, perhaps, or similar-sized configurations capable of ferrying the equivalent of a small city – people and supplies – – through deep space.

The technologies are already being tested in microgravity, and are on the verge of realizing their transformative potential for the future of space exploration. ■

[1] B. Jenett and K. C. Cheung, "BILL-E: Robotic Platform for Locomotion and Manipulation of Lightweight Space Structures," in AIAA Sci-Tech, 2017.
[2] B. Jenett and C. Gregg, "Design of Multifunctional Hierarchical Space Structures," in IEEE Aerospace Conference Proceedings, 2017.
[3] H. Jackson, "Topological Optimization of a Cuboct Truss Structure Using a Genetic Algorithm," in AIAA Sci-Tech, 2017.

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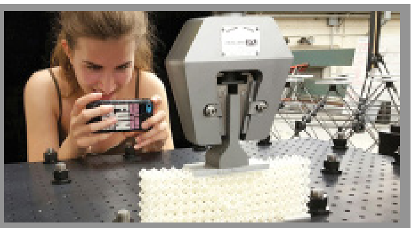
Launching at Ames



Holly Jackson has accomplished more before she finishes high school than many students have by the end of their graduate careers.

The series of events that led to her internship at NASA Ames started when she was in 6th grade, with her first science fair. For a 7th grade science fair, she designed a robot that fires billiard balls to scientifically assess how the cue ball affects other balls during the break and other shots. Her 8th grade experiment involved sewing – testing the strength of a variety of stitching techniques, materials, and threads. It took her to the state science fair and then to a national one, the Broadcom MASTERS, in Washington DC. She won the competition, met the president of the United States, and – perhaps most significantly – met the Ames Chief Technologist. Harry Partridge invited her to tour Ames and meet researchers doing work related to her interests. The visit eventually led to her internship in Kenny Cheung's lab.

On joining Cheung's lab, Holly immediately began working on truss structures, the unifying theme of both her work at the lab and her collaborations with Ben Jenett and others in the lab. Her first project involved mastering the software and then developing a program to model different truss structures. Then, inspired by seeing the cross-section of a bird bone, which she observed had a dense lattice in areas subjected to pressure when the bird lands but is otherwise delicate and light, she began working on concepts to subtract material or change the components in order to alter the qualities of a truss. On Dr. Cheung's suggestion, she adopted her current technique, the use of genetic algorithms to select which voxels to subtract from the structures.

Her current work has direct application to Jenett's project, but in the future might influence other structures, including the Mission Adaptive Digital Composite Aerostructure Technologies (MADCAT) project led by Sean Swei and Cheung.

Chief Scientist's Corner

NASA is committed to providing public access to science data. This increased public access is intended to accelerate the dissemination of fundamental research results to advance scientific knowledge and help ensure the nation's future prosperity. NASA- Funded Research Results can be found at: https://www.nasa.gov/open/researchaccess.

In addition, access to research materials is critical for a state of the art innovative research and technology center, such as NASA Ames. The NASA Ames Research Library supports the information needs of Ames' diverse community. The library staff are valued information service partners known for providing research expertise and delivering relevant/targeted timely results by navigating the ever-expanding information universe. We encourage all staff to visit and utilize Ames' extensive library services.

To assist in work-life balance and to provide additional access to research materials, the Santa Clara County Library (SCCL) services are being brought to your doorstep. Starting January 31st, the SCCL Bookmobile will stop at Ames every other Tuesday. The Bookmobile brings all the latest releases for free. It carries materials for all age groups and all types of formats: books, audiobooks, ebooks, music, movies, video games and more.

The Office of the Chief Scientist (OCS) is here to assist in your research endeavors. If you would like our assistance, please feel free to contact us at arc-ocs@mail.nasa.gov or visit our website:

- Jacob Cohen

Upcoming Activities & Events

Upcoming APPEL Courses - Select

Writing for Technical Professionals
February 22, 2017 • Location: LaRC

Managing Virtual Teams
February 27-28, 2017 • Location: GRC

Performance Based Statement of Work
March 7-8, 2017 • Location: ARC

Strategic Thinking for Project Success
April 24-26, 2017 • Location: ARC

Agile PM: Keys To Getting Started
April 25-27, 2017 • Location: ARC

Creativity and Innovation
May 1-3, 2017 • Location: MSFC
May 16-18, 2017 • Location: KSC

Events & Conferences

April 26-28, 2017
CubeSat Developers' Workshop
CalPoly, San Luis Obispo, CA

May 1-2, 2017
Interplanetary Small Spacecraft Conference
San Jose State University, CA

External Solicitations

National Science Foundation
Advanced Technologies and Instrumentation
Development and construction of state-of-the-art astronomical detectors and instruments for the visible, infrared, submillimeter, and radio regions of the spectrum
https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5660&org=AST&sel_org=AST&from=fund
Proposals Due: November 1, 2017

National Science Foundation
Biological Sciences - Active Funding Opportunities
https://www.nsf.gov/funding/pgm_list.jsp?org=BIO
Multiple Solicitations