Xwing builds the suite of technologies necessary for pilotless flight of aircraft

- Hardware and software suite that enables tele-operations
- Starting with cargo applications to prove technology and refine autonomous tech
- First gate-to-gate autonomous cargo flight in August 2020
Ziptilion: The Memory Compression Opportunity

Dr. Angelos Arelakis, Co-founder and CTO, ZeroPoint Technologies

Underutilized memory resources
Up to 70% redundant information is stored in today’s standard managed memory

Benefits
Robust memory compression across diverse workloads
Memory expansion of 2 - 3x
Memory bandwidth improvement by 30-50%
Efficient use of energy
A data center could save 20% of the energy cost per year.

Compressed Managed Memory: Increases system performance with up to 50% at unmatched energy efficiency

The Memory Bottleneck
Limited memory bandwidth and capacity restrict system performance and blow the power budget

Data curve from IDC/EMC Digital Universe reports 2008-2017, Compute curve HPE analysis

Data explosion: Emerging applications demand increasing memory capacity and bandwidth

General purpose and lossless compression
Compression training with realtime hardware accelerated data analysis
Transparent to the operating system and user
Latency on the order of nanoseconds
38 registered and 16 issued patents


Source: Micron
Creating the Perfect Climate by Applied Sorption Science
Robert Arnell, R&D Director, Munters

Untreated air carrying:
- Moisture
- Volatile organic compounds
- CO₂

Treated air, supplied to the customer process, e.g. super dry air for Li battery production facilities

Competitive adsorption

\[ q_i = f(p_1 \ldots p_n, T) \]

The Sorption Rotor:
A corrugated structure made from:

- Superporous Sorptive Materials
- Support Fibers
- Binders

Success factors and challenges:
- Large specific surface and sorption capacity
- Fast mass transfer and sorption kinetics
- Fast heat transfer
- Low specific heat
- Low regeneration temperature / Heat of Sorption
- High selectivity
- Sustainable chemistry
FREESTANDING 3D GRAPHENE STRUCTURES

Cristina BANCIU

National Institute for Research and Development in Electrical Engineering ICPE-CA, 313 Splaiul Unirii, 030138, Bucharest, Romania
e-mail: cristina.banciu@icpe-ca.ro

PMMA-GN-Ni

PMMA-GN

PMMA coating

Ni etching

PMMA removing with hot acetone

Ni

CH$_4$ + H$_2$ + Ar

CVD 1000°C, 5-60 min

GN

GN-Ni

3D graphene structures

Raman spectra of freestanding 3D graphene

Current density variation according to voltage and photographic image of DSSC photovoltaic cell with 3D graphene hybrid structure counter electrode

3D graphene hybrid structures were used as counter electrode in a Dye Sensitized Solar Cell (DSSC), with a conversion efficiency of ~2.5%, in the frame of a national Experimental Demonstration Project (129PED/2017) in collaboration with the research team from IMT Bucharest [L.M. Veca, F. Nastase, C. Banciu et al. Diamond and Related Materials, 2018, 87, 70; E. Chitanu, C. Banciu, G. Sbarcea, V. Marinescu, A. Bara, P. Barbu (Prioteasa), Revista de Chimie, 2018, 69, 3376].
1.) Ultrasound Imaging is ubiquitous, and its use ranks only behind X-ray.

2.) Despite this, ultrasound exams are often inadequate or fail altogether

   **Inadequate Exam Rates:**
   - TTE inadequate: 98.4%

   **Failed Exam Rates:**
   - Obstetrics: 11-64%
   - Cardiology: 9-64%

3.) The problem is “clutter”

   Clutter is jargon for spectrally overlapping correlated noise, and it is a problem in anatomical imaging (B-Mode) and functional imaging (Doppler)

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**The Team and Support**

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**Computational Methods in Ultrasound Imaging**

**Biomedical Elasticity and Acoustic Measurement Lab**

Brett Byram (brett.c.byram@vanderbilt.edu)

Department of Biomedical Engineering, Vanderbilt University, Nashville, TN
Mitigate biases & stereotypes through embodiment

Differences across individuals, such as gender, may influence one’s interpretation of harassing behaviors. Through body-gender transfer in virtual reality, individuals experienced different virtual harassing scenarios and increased their awareness of harassing behaviors and improved implicit biases.

Mixed reality for worker knowledge support

Human workers will remain in the loop to react to unanticipated situations in the last-mile of the logistics industry. Safety education is key to reducing work-related injuries. AR-mediated on-the-job training and information can support manual laborers.

Empower learners and research through extended reality mediated applications

Virtual and Augmented Reality Laboratory
North Carolina State University
Karen B. Chen, Ph.D.
Assistant Professor
kbchen2@ncsu.edu

Examine behavioral validity in virtual reality

Virtual reality is becoming commonplace to study human behavior. Behavioral validity is the degree to which participant behavior in virtual reality approximates the real world behaviors. The cues available in virtual environments can elicit or attenuate responses and behaviors that resemble the behaviors in the real world.

Empower K-12 and college students in STEM

Learners need to have well-developed, accurate conceptions of the differences in scale represented by numbers in STEM research and practices, particularly in powers of ten. Learners embody in "Scale Worlds" in an immersive virtual environment to directly interact with scientific entities and conduct realistic size comparison that cannot be replicated in everyday experience.
Next Generation Architected Metamaterials and Automated Digital Manufacturing for High Performance Civil Infrastructure

Re-think Civil Infrastructure with new architected metamaterials (material synthesis) – High Performance Structures

New Interpenetrating Phase Composites with unprecedented properties (strength, ductility, large deformation without failure)

Positive Poisson’s Ratio ($\nu > 0$)

Negative Poisson’s Ratio ($\nu < 0$)

New Digital Manufacturing Techniques for scaling up – Robotics, Additive

Additive Repair for Aging Transportation Infrastructure – Extension of existing infrastructure lifetime

Acknowledgments
Enable the predictive design and control of plasma technologies that promote a sustainable environment, strengthen global and national security, and propel the exploration of our planet and beyond.
INTEGRATED NANO COMPUTING LAB

Brain-inspired computing using magnetic and 2D materials

New materials for spin-based devices

In-memory computing for extreme environments

DOI: 10.1063/5.0038521
DOI: 10.1002/adts.202100309
DOI: 10.1109/TNS.2021.3066070
Background

What is Aerogel?
A class of porous, solid materials that exhibit extreme material properties:
- Extremely low density
- Very good thermal insulator
- High specific area
- Lowest dielectric constant

3D Printing Technique

Freeze casting + Inkjet Printing

Control both macrostructure and microstructure (aligned porosity)

Applications

Methods
- Ultra-light, 3D Graphene Aerogel
- 3D Printing of 3D Printed Graphene Aerogel

Results

- Guinness World Records
- 3D Printed Silver Nanowire Aerogel
- 3D Printed Silica Aerogel

3D Printed Graphene Aerogel

Zhang, ...Lin, Small, 2016; Yan, ...Lin, Small, 2017; Halil, ..., Lin, Additive Manufacturing, 2020; Song, ..., Lin, AEM, 2019

3D Printed Aerogels

Dong Lin
Associated Professor
Industrial and Manufacturing System Engineering &
Johnson Cancer Research Center
Kansas State University
Deep Learning in Space and Time

fundamental goals

- learn with few data
- lower energy consumption

challenges

- climate change, hazards
- and time

digital transformation

- strength in OCR and document intelligence
• Operational and control strategies to reduce the environmental impact, cost, and inefficiency of electric power systems
• Algorithms to actively engage distributed energy resources such as storage and flexible loads in power systems operation and control
• Data-driven approaches to reduce energy burden for low-income homes

Example: balancing the variability of renewable energy production with flexible load (AC, refrigerator) consumption
Mechanics and Manufacturing of Complex polymeric Devices

**Functional and Phase Change Polymers**
*Design and synthesis of functional polymers*
*Design and synthesis of phase change materials*
*Machine Learning for optimization of printing process*

**Soft and Transient Electronic Devices**
*Fully transient Li-ion polymer battery for transient electronic applications*
*Crack formation and propagation through soft and thin electronic devices*

**Mechanics of Soft Materials**
*Understanding stress at the interface of printed dissimilar soft materials*

**Soft transient transmitters**
*Soft epidermal transient electronics and biosensors*
Research Focus
Using spontaneous speech production as a diagnostic marker of current and future Alzheimer’s disease and cognitive decline.

Experiments
1. Ask participants open-ended questions and record their spoken answers.
2. Compute characteristics of the words they’ve used.
3. Use those lexical characteristics to predict their cognitive status.

Results
Suite of lexical features is a strong predictor of current status and future decline; in particular, lexical frequency (cat vs. platypus), noun and definite article use, and lexical diversity.
Research goal: To understand the mechanisms of contaminants interaction with natural and engineer environments and to apply them to solve environmental problems

Major research areas:
1: Understanding soil biogeochemical processes and their effect on fate and transport of contaminants.
   - Investigate the partition of contaminants in environmental interphases
   - Identify chemical and biological processes and their role on speciation
2: Rhizosphere engineering to control the fate and transport of contaminants.
   - Harness microbe-plant interaction to control contaminant bioavailability
   - Promote resource recovery through bioaugmented phytorecovery
3: Microbial community engineering for resource recovery optimization from wastewater activated sludge
   - Microbial community enrichment to produce polyhydroxyalkanoates (PHA) from wastewater

Applications: to solve current and future challenges, such as environmental pollution, deterioration of ecosystems, and depletion of resources, with the help of ubiquitous materials to reduce waste production, to engineer effective systems for waste reuse, and to minimize waste impact.

How can we serve and protect our communities in the most efficient and safe way?
Motivation

Intrinsic low-dimensionality is often a crucial ingredient for the interpretability of high dimensional statistical models.

This is called the bet on sparsity principle.

For example: MNIST digits are vectors with 784=28x28 pixels but the effective dimension is in the order of 10. ISOMAP face database has images of size 4096=64x64 (256 levels of gray) whereas the correct intrinsic dimension is only 3 (vertical, horizontal pause and lighting direction).

We address the issue of « true » (sub-linear) sparsity in the average case approach for rank-one matrix estimation.

Sparse spiked Wigner matrix model

\(X = (X_1, \ldots, X_n) \in \mathbb{R}^n\) with iid

\(X_i \sim P_{X,n} = \rho_n P_0 + (1 - \rho_n) \delta_0\) with \(\rho_n \to 0^+\)

One has access to the noisy data matrix:

\[W = \sqrt{\frac{\lambda_n}{n}} X \otimes X + Z\] where \(\lambda_n = \text{SNR} \to +\infty\)

We investigate statistical as well as algorithmic phase transitions in regimes:

\(\rho_n \to 0^+\) and \(\lambda_n \to +\infty\).

In a nutshell: for Bernoulli or Bernoulli-Rademacher \(P_{X,n}\), the MMSE and MSE (of AMP) display 0-to-1 phase transitions on widely different scales.

Regimes with phase transitions

Statistical phase transition:

\(\rho_n = \Omega(n^{-\beta}), \quad \lambda_n = 4\rho_n^{-1} |\ln \rho_n|\)

Algorithmic AMP phase transition: for a number of iterations \(t = o(\frac{|\ln n|}{\ln \ln n})\) a transition occurs for \(\rho_n = \Omega((\ln n)^{-\alpha})\), \(\lambda_n = \omega \rho_n^{-2}\)

These are established for Bernoulli and Bernoulli-Rademacher \(P_{X,n}\) and any \(\beta < 1/6, \alpha > 0\).

All-or-nothing for the MMSE:

As the sparsity decreases, information-theoretic all-or-nothing transitions appear both at level of the mutual information and the Bayes-optimal MMSE, around a SNR that diverges as \(\rho_n \to 0^+_+\)

All-or-nothing for the MSE of AMP:

The same phenomenon happens for the MSE of the Approximate Message-Passing algorithm, but at a very different scale of SNR: the computational gap diverges as \(\rho_n \to 0^+_+\).

Computational-to-statistical gap

Both statistical and computational phase transitions are established for \(\rho_n = \Omega((\ln n)^{-\alpha})\). The phase transitions are separated by a gap:

\(\lambda_{\text{stat}} \sim 4\rho_n^{-1} |\ln \rho_n| < \lambda_{\text{AMP}} \sim (e\rho_n)^{-2}\)

Conjecture: this still holds for \(\rho_n = \Omega(n^{-\beta})\).

Methods

• We extend the adaptive interpolation method to sub-linear sparse settings and compute the mutual information. Informally, the theorem states:

\[I(X; W) \approx n \rho_n |\ln \rho_n| \inf_{q_{\text{AWGNC}}} \left\{ \frac{1}{2} (q - \rho_n)^2 + I_4(X; \sqrt{n} q X + Z) \right\}\]

\(X \sim P_{X,n}; Z \sim \mathcal{N}(0,1), \quad I_n = \text{mutual info of AWGNC}\)

• Then use the I-MMSE relation to deduce the MMSE.

• Analyze an \(n\)-dependent state evolution (SE) reflecting that \(\rho_n, \lambda_n\) change as \(n\) grows. Use concentration arguments to show that SE gives a finite sample approximation of AMP for \(t = o(\frac{|\ln n|}{\ln \ln n})\).

References

• Full version of this work: arXiv:2006.07971
• G. Reeves, J. Xu, I. Zadik. The all-or-nothing phenomenon in sparse linear regression. COLT, vol 99 of PMLR, pages 2652-2663, 2019
Understanding variability of biologic macrostructures in vaccine and gene therapy manufacture using TEM and data analysis

Lab workflow

Taxonomy and critical parameter discovery workflow

Extraction

Distance spaces (X,d)

Critical parameters and features
"A good science fiction story should be able to predict not the automobile, but the traffic jam" – Frederick Pohl

A nation prototyping the future for the benefit of all

Strategic foresight, weak signals, speculative design, futures literacy, futures thinking, anticipatory innovation, mission-oriented innovation, emerging technologies
Materially Transforming Electronics with Graphene

The unique properties of graphene, the first 2D wonder material

- High conductivity
- Thermal conductivity
- Low resistivity
- Chemical stability
- Flexibility
- Transparency
- Super strength
- Impermeability

Hall sensors for applications including e-mobility & quantum computing

Scaling with commercial-quality, transfer-free & device ready graphene

Reproducible, high quality biosensors for rapid, point-of-care diagnostics

Paragraf was spun out from Cambridge University, now employing >75 people

Next gen comms & compute; transistors, modulators, detectors, THz & IR applications

Paragraf, Dr Simon Thomas FREng, CEO

www.paragraf.com
Data-Driven Methodologies for Advanced Manufacturing
Paul Witherell, PhD  Engineering Laboratory  National Institute of Standards and Technology

Research In:
- Characterization
- Registration
- Curation
- Exploration
- Simulation
- Analysis

Based On:
- Systems Integration
- Information Modeling
- Machine Learning
- Model Composition
- Measurement Science
Bioinspired Materials for Healthcare and Sustainability

Study and understand how natural materials function

Develop biotic and abiotic materials synthesis platforms

Design bespoke bioinspired materials

Application Areas:

- sustainable plastics
- tissue engineering & repair
- antibiotic & antiviral surfaces
- biomanufacturing & drug delivery