ECE516 Syllabus, year 2019
Intelligent Image Processing

Learn fundamentals of "Wearables", VR/AR, and Intelligent Sensing and Meta-Sensing for Wearables, Autonomous Electric Vehicles, and Smart Cities.

Winter/ 2019, 41 lectures + 11 labs.
Website: http://wearcam.org/ece516/

Instructor:	Professor Steve Mann, (mann@eyetap.org), http://wearcam.org/bio.htm
TAs:	Diego Defaz and Adan Moran-MacDonald
Advisors:	Arkin Ai (VisionerTech Founder), Raymond Lo (Meta Co-Founder), Chris Aimone (InteraXon CTO and Co-Founder), Ken Nickerson (Kobo Co-Founder), Ajay Agrawal (Rotman CDL Founder), Norm Pearlstine (served as the Editor-in-Chief of the *Wall Street Journal*, *Forbes,* and Time, Inc.), Ryan Jansen (Transpod Co-Founder), Nahum Gershon (Father of Human-Information Interaction), Dan Braverman (MannLab COO/General Counsel), Joi Ito (MIT MediaLab Director), and many others.
Time/Location:	Tue, Wed, Fri, 1pm, GB120 (Lab, Fri. 9am).
Lectures:	Tue, Wed, Fri 1pm-2pm in GB120, Jan.8-Apr.11.
Labs:	Fri. 9am-12noon, BA3155 and 3165, Jan 18-Apr 5.
Office Hours:	Immediately following each of the weekly 1-hour lectures. Additional office hours can be arranged with the Instructor and with the Advisors.

I. Purpose:

This course is designed to 1) provide instruction and mentorship to students interested in the art and science of understanding the world around us through intelligent sensing and meta-sensing, with an emphasis on intelligent imaging (e.g. computer vision with cameras, sonar, radar, lidar, etc.), and 2) teach the fundamentals of Human/Machine Learning in order to benefit humanity at multiple physical scales from "wearables" (wearable computing), to smart cars, smart buildings, and smart cities.

The emphasis is on fundamentally understanding technology in basic and simple ways that involve actually building devices from first-principles, to develop a deeper understanding than is possible through merely using existing tools in a shallow way.

Course lectures and instructables will be rehearsed, recorded and made available online for select students around the world.

The main course deliverable is through weekly labs which are mini-performances/demonstrations (i.e. for you to show your understanding of the material).

You will learn how to build your own wearable computer vision seeing aid for the blind, so that you can learn (1) how simple + reliable technology can help people, and (2) how to implement HuMachine Learning in a way that benefits humanity, and (3) understand wearable technologies by building them. You will also learn how to build an autonomous electric vehicle or drone.

The emphasis is on Phenomenological Augmented Reality/Wearable Computing/Humanistic Intelligence, operating at multiple physical scales, i.e. including vehicles as a form of Extended Intelligence.

It is expected that many students will go on to form startup ventures around their prototypes and labs, through ongoing guidance and support. [See also APS1041.com which some ECE516 students also take].

Guest lecturers and mentors include Founders, CEOs, and CTOs from venture-capital backed companies in the U.S., Canada and China, many of which were born in Professor Mann's Toronto lab, as well as connections with Mannlab Silicon Valley and Mannlab Shenzhen.

II. Overall Course Philosophy, Aims and Outcomes:

In this course you will learn how to build your own wearable computer and your own self-driving personal electric car or drone.

The emphasis is on teaching you fundamental physical sciences and engineering so that you can learn how to think (and do) for yourself.

Many universities have become tax-free hedge funds to serve the interests of big corporations and big government. They train students to become a source of cheap labour for big pharma, big data, big science, and big watching (surveillance). They train students to become a small specialized cog in a big machine.

Many courses are no longer taught by professors who are authors of the textbooks or who are authorities on the subject matter, or who even show up to the labs to work directly with the students.

Therefore, what we aim to do in this course is restore the balance in favour of the student, i.e. to empower the student with concepts like "little data" (distributed data like blockchain), "little watching" (also known as sousveillance), and human-in-the-loop AI ("HuMachine Learning") [Minsky, Kurzweil, Mann, 2013].

In this course you will learn how to think for yourself and how to build things yourself without the support of lab technicians and massive infrastructure. These are the skills that startups as well as the top companies are looking for, and certainly the skills you need to create your own startup.

See http://wearcam.org/ece516/philosophy.htm for more on the philosophy of ECE516.

III. Specific Learning and Evaluational Outcomes*:*

By the end of this course, students will:

- Know how to build a basic wearable device, such as a computer vision system for the blind;

- Understand fundamentals of personal technologies such as a small electric vehicle (e.g. mobility scooter) and fundamentals of sensing and meta-sensing associated with wearables and personal vehicles;

- Deeply understand Human/Machine Learning in the Minsky, Kurzweil, Mann [2013] sense, i.e. Sensory HuMachine Learning, along with associated mathematical transforms, i.e. Comparametric Equations, and Adaptive Chirplet Transform and Intelligent Signal Processing (e.g. to fulfill Haykin's principle of vision systems capable of cognition).

Students will learn how to quickly turn ideas into inventions through a range of time-scales ranging from quick and sloppy "rapid prototyping" (rapid reduction-to-practice) to more well-made (longer time scale) prototypes designed for demonstration to others. Whereas other engineering courses often teach a slower more methodological approach akin to classical music, in this course, students will also learn "tinquiry" (tinkering as inquiry), more akin to jazz music (i.e.. quick improvisation, often making working prototypes to turn ideas into inventions in 90 minutes or less). Formal large lectures will be given, but there will be ample one-on-one and small-group mentorship and meta-mentorship as well. For meta-mentorship, we offer to help you bring in friends and associates of your own, who you are comfortable with already, as co-mentors.

The course will use the Instructables.com website to help in teaching. The course instructor devotes a lot of time to individual one-on-one mentorship of students, and will respond individually to each "I made it" post. Completing one or more of these Instructables will give students the opportunity to demonstrate aptitude for making things, and to get a sense of what kinds of topics the course instructor is best equipped to help you with.

IV. Course Readings:

The course textbook is "Intelligent Image Processing" by Steve Mann, published by John Wiley and Sons, and available in the University of Toronto bookstore.

Selected additional readings, articles and publications from http://www.eyetap.org/publications and from http://weartech.com, as well as AR Metavision content will also be made available. Additional readings and Instructables will be posted on http://wearcam.org and http://www.instructables.com/member/SteveMann/instructables/ from time-to-time.

V. Course Evaluation and Grading Procedures:

- Closely Supervised Work: 40% (in-lab reports, testing, participation, field trials, etc.).
- Not Closely Supervised Work: 25% (take-home assignments or the portion of lab reports done at home)
- Final exam: 35%. Exam is open book, open calculator, but closed network connection.

Lab periods are for grading. It is presumed that you will arrive at the lab with a working assignment to show and be graded in the lab (i.e. the prelab is to get it working).

VI. Labs:

The majority of your grade comes from the labs, and the lectures are primarily in service of the labs. The professor attends and runs the labs directly (unlike many professors who don't care to even come to all the labs, or even to most of the labs!).

The lab periods are for you to show your work and for you to connect with the professor and TAs and other members of the class. This is your opportunity to show off and see and be seen in the world of smart technologies.

The most important part of this course is the labs which offer authentic direct mentorship with high degree of involvement from the professor and other leading experts in sensing, meta-sensing, and machine learning.

There are 11 labs with projects in these six areas:

1. Complex-Valued Signal Generators and Signal Generators Using Trochex Numbers (rotary, i.e. trochially complex numbers), and Polex Numbers (plurally polyphasic systems).
    - Build your own signal generator that produces a complex-valued output. You can't buy these anywhere! (We should all start a company selling them!!!). Here you will learn all about complex numbers and you will fundamentally understand the difference between positive and negative frequencies. You will finally understand complex numbers at a deeply intuitive level.
    - Extend this to trochex numbers (e.g. with real, remaginary, and umaginary components). Connect it to a motor and watch the motor spin.
    - In your next lab you will use this signal generator as the basis for a wearable seeing aid for the blind. In later labs you will use this signal generator as the foundation upon which to build autonomous electric vehicles!
2. Phase-coherent detection for active computer vision:
    - Active vision systems (sonar, radar, lidar): Build your own extreme broadband lock-in amplifier;
    - Build a sonar vision system for the blind using the amplifier together with your signal generator from your first lab;
    - Fourier transform, wavelet transform, and chirplet transform;
    - Machine learning for computer vision: Radar Vision and LEM neural network;
    - Biosignals and biosensing. In this lab ou will build an ultrasound system to image

your own heart. [Analysis of Seismocardiographic Signals Using Polynomial Chirplet Transform...].
  - Brain-Computer Interfaces (InteraXon company co-founded by Mann and his students);
  - Fluid User Interfaces: Build a musical physiotherapy machine based on an array of ultrasonic lock-in amplifiers for phase-coherent sonar;
  - See and photograph sound waves, radio waves, and light waves using your lock-in amplifier.
3. Passive vision: Many courses on computer vision fail to teach the fundamental concepts of what sensing is and does. We'll begin with fundamental principles by exploring first a 1-pixel camera and 1-pixel display, quantigraphic (quantifiable) sensing, and meta-sensing.
   - Begin with fundamental 1-pixel display;
   - Build your own 1-pixel camera;
   - Quantigraphic sensing: Comparametric Equations;
   - Self-driving vehicles, sensing, and meta-sensing;
   - Phenomenological augmented reality with Metavision;
4. Trochography and trochogrammetry: Understanding 3 phase motors and electric vehicles. Connect your polex-valued signal generator and use it as the heart and soul of an electric vehicle;
5. Build your own autonomous "ehicle" (e-vehicle) or mobility scootor, or other mobility aid to help the physically challenged...
6. Your final project of your own choosing...

VII. Opportunities

Prof. Mann is widely known as the inventor of HDR (High Dynamic Range) imaging used in more than 2 billion smartphones, and in his role as a founding member of the IEEE Council on Extended Intelligence and the Chair of the Silicon Valley Investment and Entrepreneurship Forum, is well-connected to industry. We have vacancies in Toronto, Silicon Valley, and Shenzhen China, and seek people who are well-grounded in fundamentals leading to deeply understanding “wearables”and HuMachine-Learning/Extended-Intelligence (HI) for autonomous vehicles and smart cities. Ford Motor Company is collaborating with us and we’re looking for people for this as well. Prof. Mann has also helped a number of students get into MIT (his alma mater) and Stanford (where he spent a lot of time living and working).

Doing really well in this course is your chance to impress us and also to build a foundation and to build things that will impress others. Many students have said that they’ve learned more in this course than all their other courses put together. Here’s your chance to “put your feet on the ground” and build a solid foundation under all of what you do.

Please see http://wearcam.org/ece516/opportunities.htm for summer and fall 2019 opportunities in MannLab.com as well as at University of Toronto, MIT, Stanford, Ford Motor Company, etc..

Reading Week, Feb. 16-24: Optional trips to MannLab Silicon Valley, MannLab Shenzhen, and MannLab Toronto + InteraXon for interested parties creating business activity + connections, etc..

VIII. Academic Integrity

Each student in this course is expected to abide by the University of Toronto Code of Behaviour on Academic Matters. Any work submitted by a student in this course for academic credit will be the student's own work.

You are encouraged to study together and to discuss information and concepts covered in lecture and the sections with other students. You can give "consulting" help to or receive "consulting" help from such students. However, this permissible cooperation should never involve one student having possession of a copy of all or part of work done by someone else, in the form of an e-mail, an e-mail attachment file, a diskette, or a hard copy.

Should copying occur, both the student who copied work from another student and the student who gave material to be copied will both automatically receive a zero for the assignment. Penalty for violation of this Code can also be extended to include failure of the course and University disciplinary action.

During examinations, you must do your own work. Talking or discussion is not permitted during the examinations, nor may you compare papers, copy from others, or collaborate in any way. Any collaborative behavior during the examinations will result in failure of the exam, and may lead to failure of the course and University disciplinary action.

IX. Accommodations for Students with Disabilities

In compliance with the University of Toronto policy and equal access laws, I am available to discuss appropriate academic accommodations that may be required for student with disabilities. Requests for academic accommodations are to be made during the first three weeks of the semester, except for unusual circumstances, so arrangements can be made. Students are encouraged to register with Student Disability Services to verify their eligibility for appropriate accommodations.

We are also extremely well-versed in seeing aids for the visually impaired, as well as in electric mobility aids.

X. Inclusivity Statement

We understand that our members represent a rich variety of backgrounds and perspectives. The engineering department is committed to providing an atmosphere for learning that respects diversity. While working together to build this community we ask all members to:

- share their unique experiences, values and beliefs

- be open to the views of others
- honor the uniqueness of their colleagues
- appreciate the opportunity that we have to learn from each other in this community
- value each other's opinions and communicate in a respectful manner
- keep confidential discussions that the community has of a personal (or professional) nature
- use this opportunity together to discuss ways in which we can create an inclusive environment in this course and across the University community

Appendix. Available Course Equipment

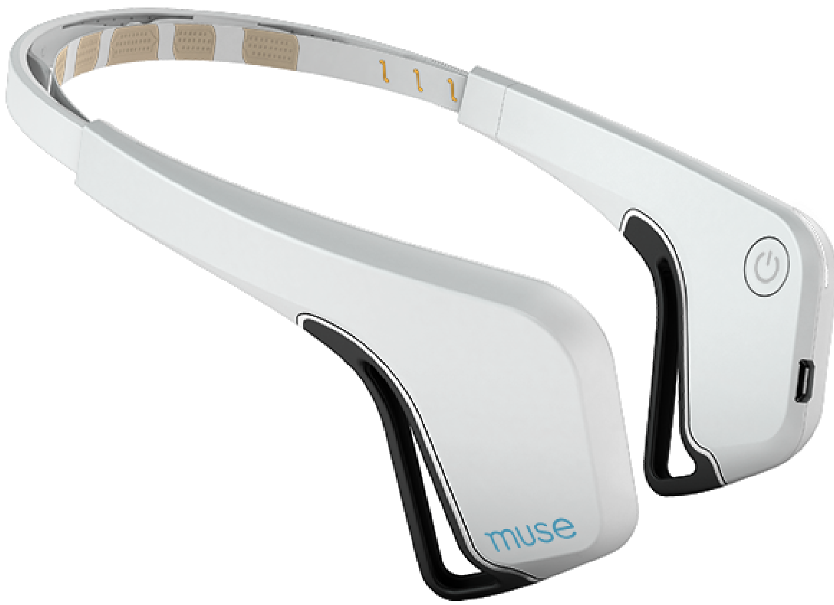
VisionerTech VMG-PROV

Related link: https://www.youtube.com/watch?v=T0m0qGA8xhk

Meta 2 Augmented Reality Eyeglasses

Related link: https://www.metavision.com

Muse Headband

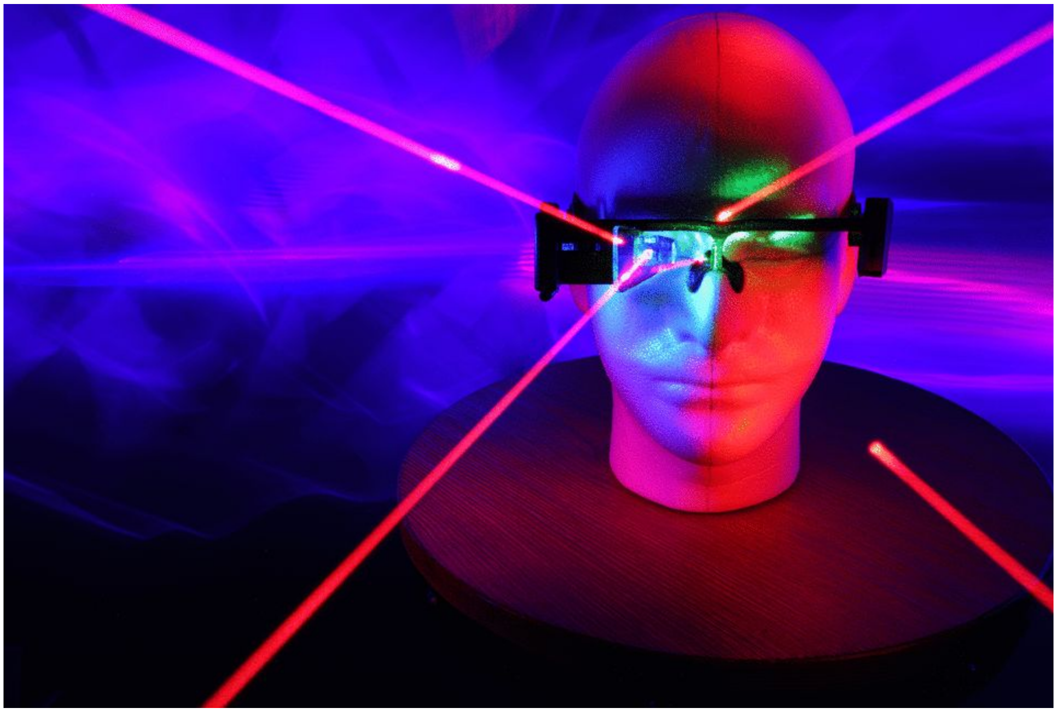


Related link: https://www.choosemuse.com

Muse Safilo Eyeglasses

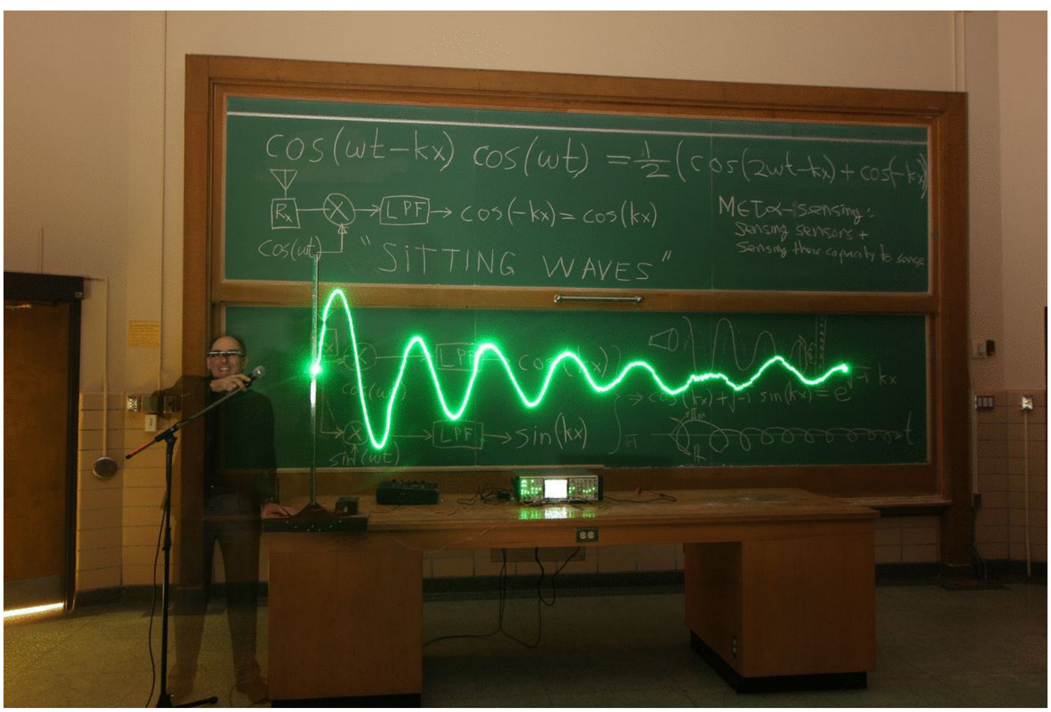
Related link:https://www.youtube.com/watch?v=5CZtoYbfbHU

Open EyeTap



Related link: https://www.openeyetap.com

“MannLab x SYSU” Lock In Amplifier & Phenomenological Augmented Reality



Related link: http://www.wearcam.org/par/