MIT Beaver Works Summer Institute

MIT Beaver Works Summer Institute 2018

Autonomous RACECAR Grand Prix

Autonomous Air Vehicle Racing

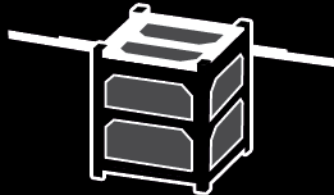**Autonomous Cognitive Assistant**

Data Science for Health & Medicine

Hack A 3D Printer

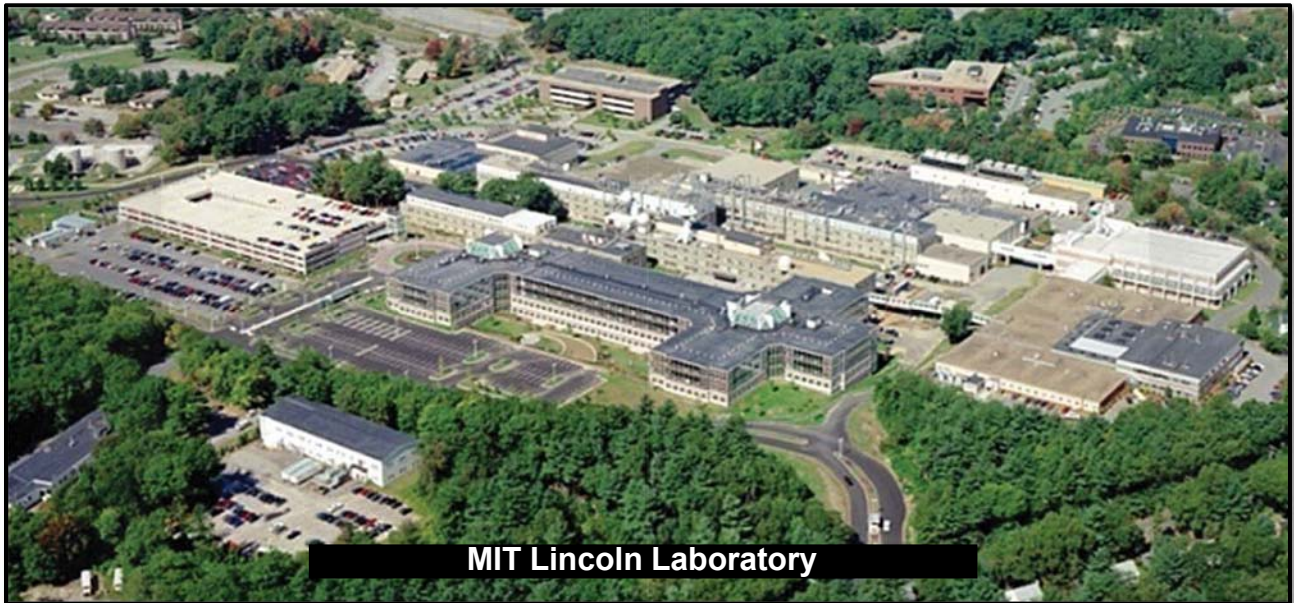**Embedded Security and Hardware Hacking**

Build a CubeSat

UAS-SAR

Unreliable Media

20TH CENTURY HEADLINES
REWRITTEN TO GET MORE CLICKS

Massachusetts Institute of Technology

MIT Lincoln Laboratory

MIT Lincoln Laboratory / School of Engineering Beaver Works

MIT Beaver Works Summer Institute

The MIT Beaver Works Summer Institute is a rigorous, world-class STEM program for talented rising high school seniors. The 2017 program featured three project-based, workshop-style courses. In the RACECAR course, students programmed small robotic cars to autonomously navigate a racetrack. For the Autonomous Air Vehicle Racing challenge, students designed quadrotors to fly autonomously in an aerial race. Students in the third workshop built their own Alexa-like cognitive assistants by applying techniques from artificial intelligence.

The 2017 MIT Beaver Works Summer Institute was a complete success thanks to the enthusiasm of our students, the dedication of our instructors, and the hard work of our team members. We partnered with 49 high schools to recruit the future engineers who participated in our program. We had the pleasure of working with 98 students, 63 of whom joined our program from outside Massachusetts.

In 2018 we hope that early-adopting high schools will implement our program for their students and join the final race day events. Our courses would be just the beginning of the national and then international expansion of engineering education we want the Beaver Works Summer Institute to spark.

In the coming years, we will integrate new programs into this initiative, increasing participation substantially. We will support high school STEM teachers who use our teaching materials to help better prepare their students for college and beyond. We will also help other universities and high schools create similar programs, working to build a network of institutes to collectively improve engineering education worldwide. Contact us at bwsi-admin@mit.edu for information on how to adopt this program into your school curriculum. If you are an international team that would like to participate you must have support of the MIT MISTI Program.

BWSI 2018 Timeline of Program requirements.
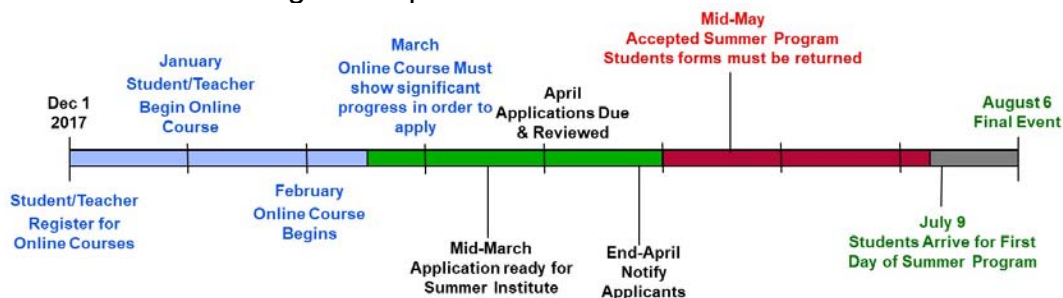
In order to attend the BWSI summer part of the program you must be a U.S. citizen or permanent resident.

Thank you for your continued support of our program.

What is Beaver Works?

Beaver Works is a joint venture between MIT Lincoln Laboratory and the MIT School of Engineering that is envisioned as an incubator for research and innovation. Beaver Works facilitates project-based learning, a hallmark of an MIT education, and leverages the expertise and enthusiasm of MIT faculty, students, researchers, and Lincoln Laboratory staff to broaden partnerships across both institutions.

The Beaver Works center located in Cambridge, Massachusetts, provides these facilities: areas for collaborative brainstorming; workshops and tools for fabricating prototype systems; and space for classroom-style instruction. Beaver Works allows students to address real-world problems and issues, engages students in hands-on learning, and demonstrates an effective strategy for teaching complex engineering concepts.

Beaver Works supports MIT student involvement in a range of research and educational pursuits, including two-semester, course-based capstone projects; joint and individual research initiatives; and Undergraduate Research Opportunities Program internships. Students involved in these projects develop innovative solutions to real-world problems and gain an exceptional experience in hands-on learning from world-class researchers.

In addition to the Summer Institute, Beaver Works is also extending project-based learning opportunities to local K–12 schoolchildren. Among these offerings have been a robotics workshop for an all-girl FIRST (For Inspiration and Recognition of Science and Technology) LEGO League team, a hands-on camera-building activity for high-school girls, and a one-day workshop on radars for students in middle school.

MIT Beaver Works Summer Institute
2018 Summer Program:
Course Overview

The MIT Beaver Works Summer Institute 2018 Summer Program will consist of the following courses. For more information on each course, see the following pages in this brochure.

Autonomous RaceCar
Beaver Works Summer Institute will offer 9 teams of students, each with its own MIT-designed RACECAR (Rapid Autonomous Complex Environment Competing Ackermann steeRing) robot, the opportunity to explore the broad spectrum of research in autonomy; learn to collaborate, and demonstrate fast, autonomous navigation in a Mini Grand Prix to ***Move... Explore... Learn...Race***!

Autonomous Air Vehicle
Beaver Works Summer Institute will offer students the opportunity to explore some new areas of research and to design their own autonomous capabilities for UAVs (unmanned aerial vehicles). The students will work in teams to develop algorithms for deployment to a commercial quadrotor, the AR Drone 2.0. They will use the Robotics Operating System (ROS), various open-source libraries, and custom algorithms to program the quadrotors.

Autonomous Cognitive Assistance (Cog*Works)
Beaver Works Summer Institute will offer students a chance to learn and use state-of-the-art machine learning tools in a program called Cog*Works: Build your own Cognitive Assistant. The program will guide students in learning and applying the foundational technologies of artificial intelligence for building cognitive assistants. Teams of students will leverage professional cognition services and open-source tools in conjunction with their own machine learning tools to develop cognitive systems.

Hacking a 3D Printer
Beaver Works Summer Institute will introduce students to the fundamentals of 3D printing and teach techniques for tuning hardware and software to optimize performance. Students will modify these components to do something completely new. Along the way students will learn how to tackle difficult problems.

Medlytics

Beaver Works Summer Institute will give students a chance to explore the exciting intersection of data science and medicine. Students will build a solid foundation in the fundamentals of probability and statistics, and learn the basics of coding and machine learning techniques through a series of online teaching modules. During the summer, students will work in groups alongside Cambridge-area clinicians and data scientists to gain hands-on experience applying advanced machine learning and data mining to solve real-world medical challenges.

Embedded Security and Hardware Hacking

Beaver Works Summer Institute will cover several cyber security topics with a focus on threats that are especially concerning for embedded systems. These topics include: embedded software security, cryptographic protocol attacks, JTAG and UART probing, side-channel analysis and fault-injection, and hardware Trojans. This background will help prepare students for the summer course, during which they will perform security assessments of multiple implementations of an embedded system: a wireless home door lock. Teams will compete to see who can find and fix the most security flaws in these systems.

Build a Cubesat

Beaver Works Summer Institute will offer students the opportunity to build, test, and fly a Cubesat. Using a 1U Cubesat (10 cm x 10 cm x 10 cm), the four-week course will guide the class through the design trades, assembly, and testing of a Cubesat with an imaging payload. The Cubesat will be launched at the first possible opportunity allowing students to track and observe their working space system.

Unmanned Air System–Synthetic Aperture Radar

Beaver Works Summer Institute will introduce students to radar imaging as they build and fly a radar on a small UAS and use it to image objects around campus. Students will work in small groups alongside engineer mentors to gain hands-on experience building, integrating, and processing data from a radar to generate images of objects around campus.

Unreliable Media

Unreliable media and "fake news" are becoming a part of everyday life. The internet can be the wild west, who and why should you trust someone or piece of content? Many international efforts are focused on automated fact checking developed through stance detection, as in the Fake News Challenge (http://www.fakenewschallenge.org/). The program's goal is for participants to build end-to-end systems to detect unreliable media content based on multimodal features. Students will be exposed to three main components: 1) feature extraction from raw data, 2) classification via machine learning techniques, and 3) decision fusion from multiple classifier scores. The program will explore tools that analyze media style by exploiting text, images, and cyber features.

MIT Beaver Works Summer Institute
2018 Summer Program:
Autonomous RACECAR Grand Prix Challenge

Program Overview

Driverless vehicle technology has been growing at an exponential pace since the DARPA Grand and Urban Challenges pushed the state of the art to demonstrate what was already possible. Commercial interest and aggressive development are being driven by Google, Toyota, Tesla, Continental, Uber, Apple, NVidia, and many other companies. There is no single technology or "killer app" available to solve the myriad perception, understanding, localization, planning, and control problems required to achieve robust navigation in highly variable, extremely complex and dynamically changing environments. This summer, Beaver Works Summer Institute will offer nine teams of five students, each with its own MIT-designed RACECAR (Rapid Autonomous Complex Environment Competing Ackermann steeRing) robot, the opportunity to explore the broad spectrum of research in these areas, and learn to collaborate, and demonstrate fast, autonomous navigation in a Mini Grand Prix to *Move... Explore... Learn...Race!*

This program consists of two components: an online course from January to May open to all interested students and a four-week summer program at MIT from July 9 to August 5 for a select group of students. The online component gives students a background in the basic concepts and tools that will be used during the summer program. The Robot Operating System (ROS) provides a rich set of tools that may be programmed at a high level with the Python programming language. A model of the RACECAR suitable for use in the Gazebo simulator allows online students to develop skills and demonstrate the basic concepts without requiring a physical RACECAR.

Completing the online curriculum will prepare students to cover the topics of Control Systems, Computer Vision, Localization, Planning, and Navigation at a more advanced level in the summer. The RACECAR is capable of achieving speeds of 40 mph, utilizing

data from real sensors processed with an onboard NVidia TX-1 embedded computer. Such a demonstration of safe, robust autonomous navigation is a significant challenge. A team of experienced MIT researchers will provide the lectures each day, covering material that reviews autonomy fundamentals and expanding on advanced topic areas in the lecturers' expertise. A series of graduated exercises, hands-on labs, and weekly challenge demonstrations will be provided to lead students through the process of developing their solutions to the fundamental problems. In addition, guest lecturers from among leading researchers in the computer science, engineering, and autonomous vehicle academic and corporate communities will provide students with insight into emerging trends in these fields.

Online Course

The online component for the Autonomous RACECAR course contains important introductory material to provide students with the background required to successfully complete the four-week summer course. A virtual machine image is provided for students to download and use on their own computers, with necessary tools preinstalled, so that they can work through both the introductory and more advanced topics and explore problems specific to autonomous vehicles.
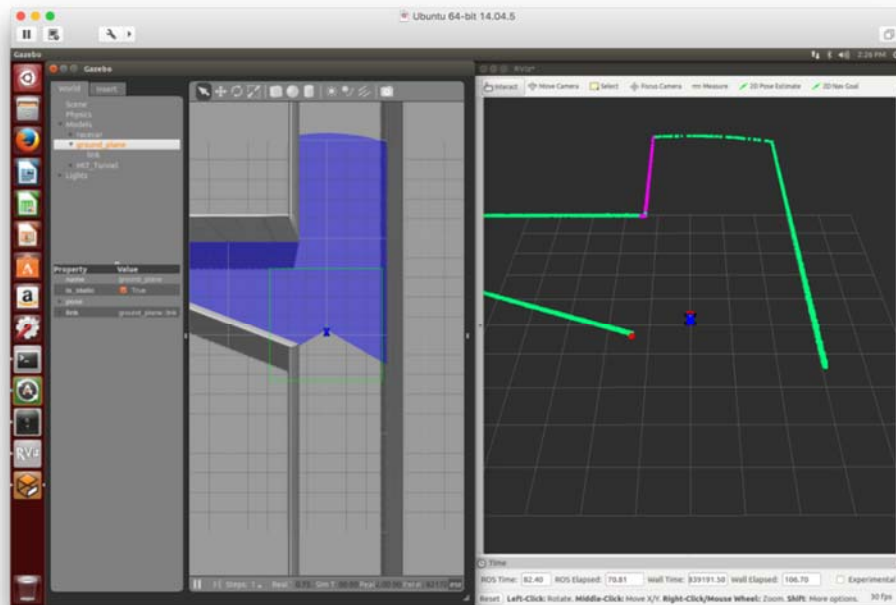
RACECAR model navigating simulated Gazebo world with synthetic sensor data

Introduction and Prerequisites

- Installing and using the virtual machine
- Reviewing the overview of the Ubuntu/Linux environment
- Learning the basics of Python programming
- Completing an introduction to the Robot Operating System

Autonomous Vehicles

- Using the RACECAR model in the Gazebo simulation environment
- Studying basic control systems
- Studying fundamentals of computer vision using the OpenCV library
- Acquiring elementary navigation and planning concepts

Summer Course

The four-week summer program is based on the BWSI 2017 course, with additional online material that prepares students to begin the summer course at a more advanced level. The curriculum is being expanded this year to emphasize the use of computer vision and machine learning techniques in autonomous navigation.
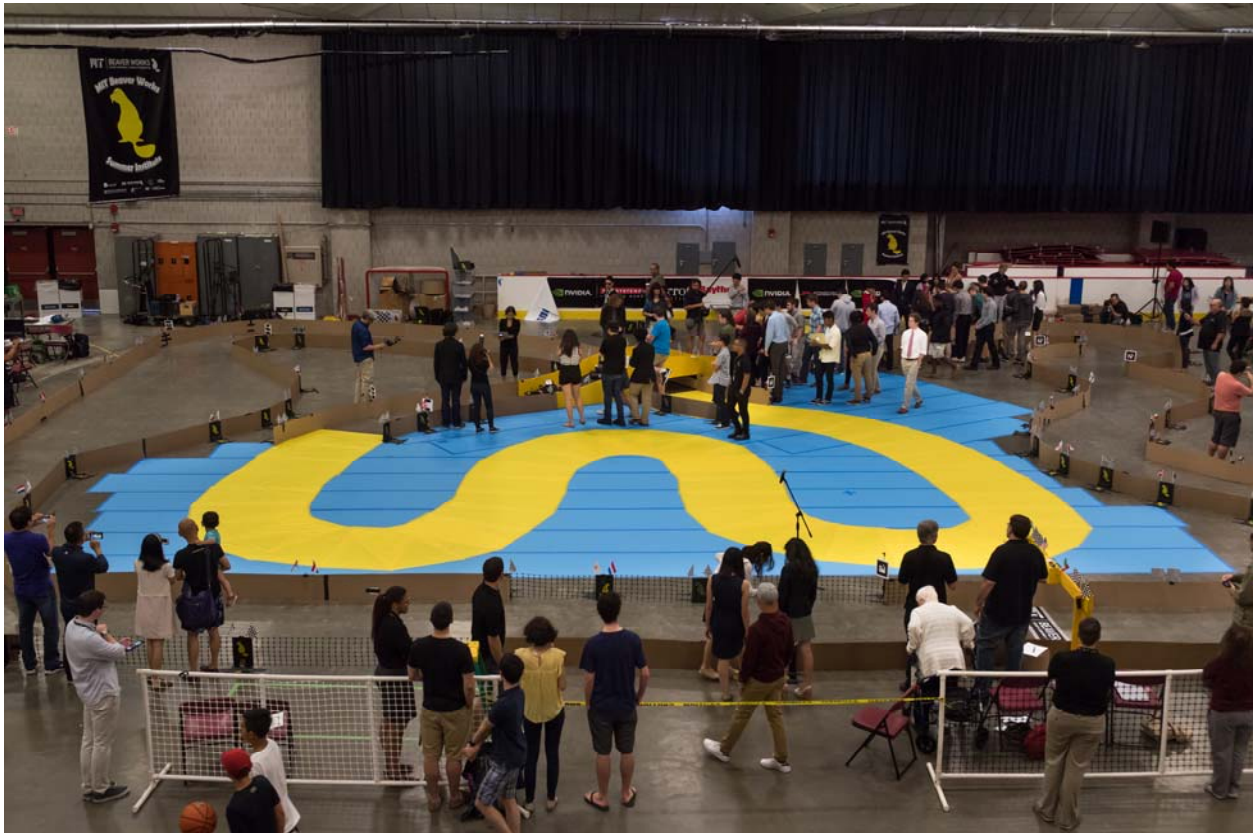
Each day in the course will consist of a mix of lectures and hands-on projects to reinforce and apply the material. The detailed topics for each week are listed below:

Week 1: Move…

- RACECAR system operation and sensors
- Robot Operating System principles
- Basic motion control and simple obstacle avoidance

Week 2: Explore…

- Computer vision techniques
- Vision-based blob, target, and object detection
- Visual navigation

Week 3: Learn…
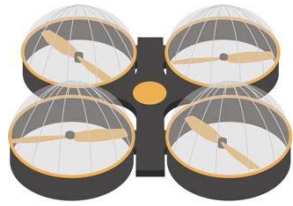
- Mapping unknown environments
- Planning paths to achieve goals
- Navigating in dynamic environments

Week 4: Race!

The final race will be held in the MIT Johnson Ice Rink on August 5, 2018. A wide variety of challenges will require that a range of behaviors be implemented to allow the racecar to make high-level decisions based on visual perception in order to complete a circuit of the track.

MIT Beaver Works Summer Institute

2018 Summer Program:
Autonomous Air Vehicle Racing

Program Overview

Rapidly expanding unmanned aerial vehicle (UAV) technology has enabled a number of new application areas. The growth in UAV development is evident in the popularity of First Person View (FPV) drone racing, and interest from companies, like Amazon and others, to develop fully autonomous aerial delivery vehicles. As UAV technologies mature, they open new and exciting areas for potential research. This summer, Beaver Works will offer students the opportunity to explore some of these new areas of research, and to design their own autonomous capabilities for UAVs. The students will work in teams to develop algorithms for deployment to a commercial quadrotor, the AR Drone 2.0. They will use the Robotics Operating System (ROS), various open-source libraries, and custom algorithms that they will develop. The summer course will culminate in a competition at which the students will apply the knowledge gained from the four-week program's projects and lectures to a series of racing challenges.

This program consists of two components: an online course from January to May open to all interested students and a four-week summer program at MIT from July 9 to August 5 for a small group of students. The online component gives students a background in the course material, and provides a solid mathematical foundation that will be critical when completing the more advanced topics of the summer course. The skills the students develop during the summer will be demonstrated in a simulation environment as well as on an AR Drone 2.0. Students will demonstrate basic implementations of control and autonomy after each unit of instruction. These lessons will build upon previous instruction to enable students to develop algorithms so that a quadrotor can autonomously navigate a UAV racecourse designed for the summer program.
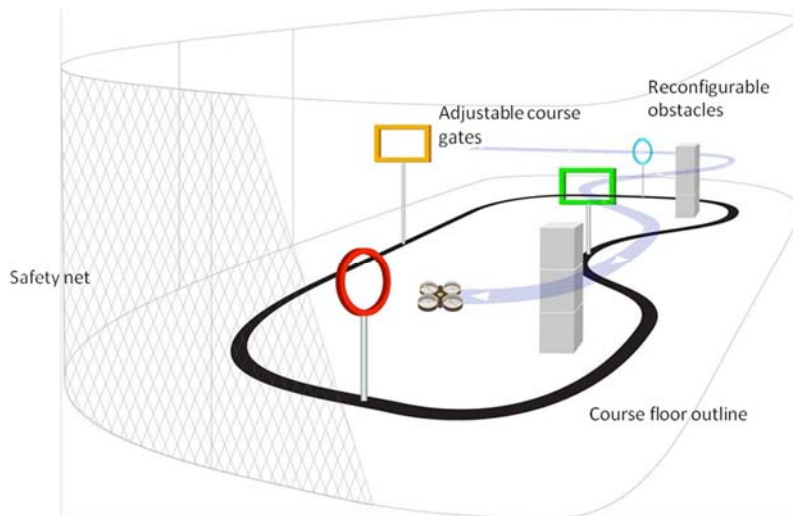
Conceptual UAV Race Course

Online Course

The online component for the Autonomous Air Vehicle Racing course will contain important introductory material that will provide students with the background required to successfully complete the four-week summer course. In addition to the introductory material, the online course will include more advanced, quadrotor-specific material so that students can begin to explore problems specific to autonomous aerial vehicles.

Introduction and Prerequisites

- Introduction to quadrotors
- Linear algebra
- Basics of matrix mathematics
- Introduction to probability and statistics
- Computer programming fundamentals

Autonomous Aerial Vehicles

- Flight geometry
- Actuators and control
- State estimation
- Sensing
- Basic control theory
- Computer vision
- Visual motion estimation

Summer Course

The four-week summer program will be structured to provide the students with projects and hands-on exercises. The program will apply and expand upon the online course material, leading to multiple competitive team challenges in autonomous UAV control. Each day the course will consist of a mix of lectures and hands-on projects to reinforce and apply the material. A team of experienced MIT researchers will provide the lectures, covering material that reviews UAV and autonomy fundamentals and expanding on advanced topic areas in the lecturer's expertise. Hands-on projects will enable the students to apply each lecture, working toward a capability for autonomous UAV racing by using the provided AR Drone 2.0 and associated experimentation equipment. In addition, the course is lining up guest lecturers

from among leading researchers in the computer science, autonomy, and air vehicle academic and corporate communities to provide the students with emerging trends in these fields. Upon completion of the four-week course, the students will have developed an understanding of autonomous systems development; including controls, flight dynamics, navigation, and computer vision.

The course curriculum is new this year and is still in development at this time, but the current plan extends over three weeks of instruction and hands-on practice and one week of team challenges, culminating in the final UAV racing challenge. The detailed topics for each week are listed below:

Week 1: Flight

- Quadrotor design
- Quadrotor dynamics
- Quadrotor components

Week 2: Vision

- Image formation
- Edge detection
- Image filtering
- Object detection

Week 3: Control

- Control systems
- State estimation
- Navigation and planning

Week 4: Racing Challenges

The final week of the course will focus on hands-on team projects in autonomous UAVs and racing challenges, leveraging the lessons learned from the first three weeks of the course.
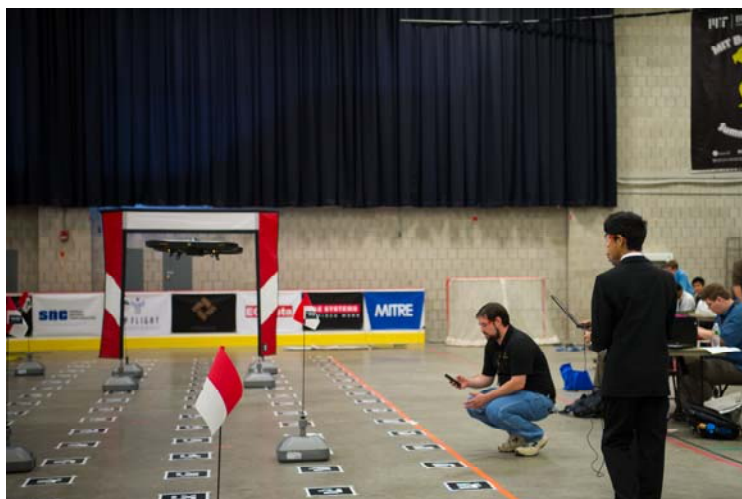
MIT Beaver Works Summer Institute

2018 Summer Program:
Autonomous Cognitive Assistant

Program Overview

Artificial intelligence research has achieved a dramatic resurgence in recent years, as innovation of novel deep learning and other machine learning tools has enabled machine performance surpassing humans in specific cognitive tasks. New records in "machine thinking" seem to be set almost daily. This summer, the BWSI is offering students a chance to learn and use the state-of-the-art machine learning tools in a program called Cog*Works: Build your own Cognitive Assistant. The program will guide students in learning and applying the foundational technologies of artificial intelligence for building cognitive assistants. Students who have successfully completed the online course will be considered for participation in the summer program in which teams of students will leverage professional cognition services (e.g., Amazon Alexa/Echo) and open-source tools in conjunction with their own machine learning tools to develop cognitive systems. The program will be divided into modules during which students will implement and explore algorithms in core areas of natural language processing and machine cognition. These capabilities will be composed to create end-to-end cognitive assistants that will compete against each other at the end of the program.

This program consists of two components: (1) online course from January to May 2018, open to all interested and committed students, and (2) a four-week summer program at MIT for a small group of students, July 9–August 5. During the course, the students will be trained to understand the basics of Python, Git, natural language processing, and machine learning through a series of online teaching modules. Students will build services that are both functional and fun. By participating in the online and/or onsite portion of the program, students will develop experience in an area of computer science that is poised to play a critical role in shaping future technologies and applications across many industries.

Online Course

The online component for the Cog*Works course will contain important introductory material that will provide students with the background required to successfully complete the four-week summer course. In addition to the introductory material, the online course will include more advanced machine learning–specific material that will enable students to begin exploring problems specific to cognitive assistants.

Introduction and Prerequisites

- Introduction to Python
- Git & Github management tools
- Perspectives on machine learning

Autonomous Cognitive Assistants

- Advanced NumPy
- Simple image classification with Python
- Introduction to neural networks
- Introduction to Web Services
- Introduction to Microsoft Cortana ©, and Amazon Alexa © services
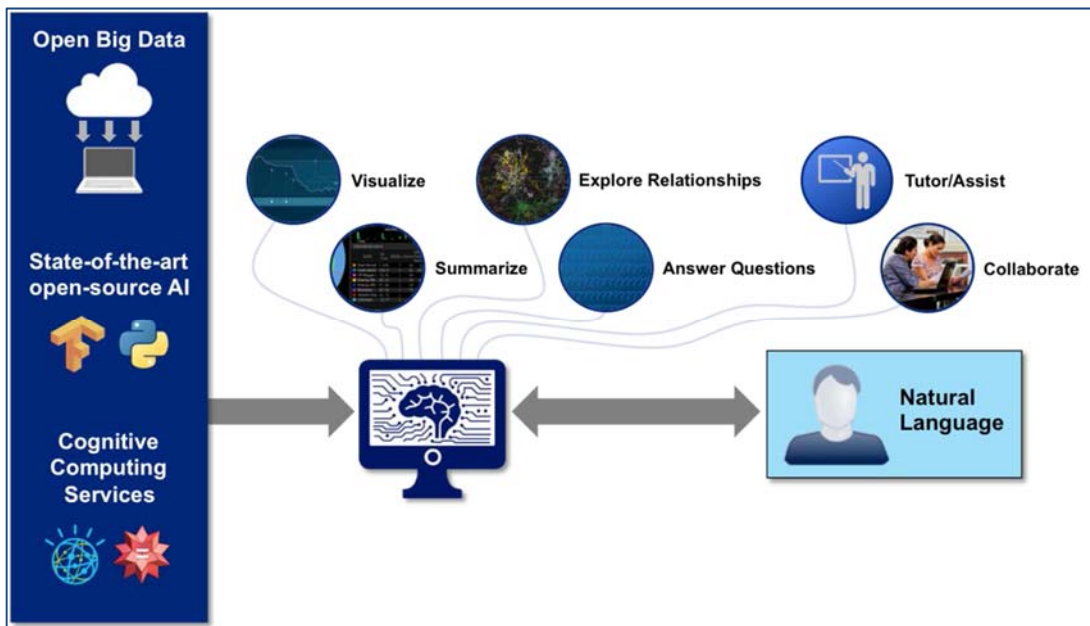
Summer Course

The four-week summer component of the BWSI Cog*Works course aims to guide students through the process of creating their own cognitive assistants. Daily lectures from course instructors and guest speakers will solidify and expand upon the content from the online portion of the course. Students will collaborate in small groups to complete milestone projects that are based on their lecture materials. These projects will allow for creative customization and enhancements from the students, and weekly awards will be given to the group(s) with the most "interesting" projects. Ultimately, these projects will serve as the components that compose an end-to-end cognitive assistant.

The following is a rough outline for the summer course:

Week 1: Audio

- Python/NumPy/Github review
- Audio recording, sampling, and encoding
- Discrete Fourier transforms and their applications
- Pattern recognition in audio data
- Audio capstone project

Week 2: Visual

- Review of machine learning concepts
- Coding your own autograd library
- Training dense neural networks
- CNNs and RNNs
- Visual capstone project

Week 3: Language

- Representing written language numerically
- Document comparison and summarization
- Training a language model
- Training word embedding
- Information retrieval
- NLP capstone project

Week 4: Challenges

- Customize your own neural network

MIT Beaver Works Summer Institute

2018 Summer Program:
Hacking a 3D Printer

Program Overview

Additive Manufacturing (AM), and in particular 3D printing, has become a powerful tool in scientific, engineering, and industrial applications. As the technology becomes more pervasive, we continually look for applications and ways to use these tools in innovative ways. One of the key advantages to the open nature of this technology is the ability to modify a printer to operate in a way that was not originally intended.

In summer 2018, BWSI will host the new Hack a 3D Printer course. The goals of this course are to introduce the fundamentals of 3D printing, show how hardware and software can be tuned for optimal performance, and teach techniques to modify these components to do something completely new. Along the way students will learn how to use engineering skills to tackle a difficult problem.

Teams of students will spend four weeks at MIT building, coding, using, and hacking their own 3D printers. The first week will be dedicated to the "nuts and bolts" of AM as students build their own printers. When the printers are complete, students will learn how to use and tune these devices. The second week is dedicated to engineering and design principles as students tackle a number of team-based challenges. Using computer-aided design (CAD) the students will need to design and 3D print their own solutions to problems inspired by real life. Week 3 will focus on hardware and software modifications to the printers they have built. Starting with small instructor-led tweaks to improve performance, the students will ultimately plan a major hardware modification to their printers. The final week is dedicated to implementing their hardware modification, and designing and printing an engineered solution with their "hacked" printer.

Online Course
Before arriving on campus students will be required to complete an online course on AM. The course will introduce students to key math, science, and engineering concepts that will be required on day one. A large portion of this online course will be dedicated to CAD, and students will be required to submit completed CAD drawings.

Introduction and Prerequisites
- Introduction to Additive Manufacturing
- Geometry and Coordinate Systems
- Introduction to Materials Science

Computer Aided Design (CAD)
- Introduction to CAD
- OnShape Tutorials

Summer Course
During the four-week on-campus course, students will learn the details of AM primarily through hands-on activities and experimentation. Daily lectures will provide information and direction, but students will need to apply sound reasoning to solve a variety of engineering challenges. Guest lecturers from MIT and Boston-area companies will help provide context and specific applications of these technologies. Visits to MIT labs using AM and other emerging technologies will be included.

Week 1: Building a 3D Printer
- 3D printer hardware build
- CAD review
- Slicing and g-code
- Printer tuning and optimization

Week 2: Engineering Design Principles
- Designing with constraints
- Limitations of material properties
- Working with a customer
- AM in the real world

Week 3: Printer Modification
- Novel materials
- Advanced CAD and slicing
- Customizing g-code

Week 4: 3D Printing Challenge

The final week will be dedicated to implementing and optimizing a major printer modification. Using the modified printers, students will develop a solution to an engineering challenge.

MIT Beaver Works Summer Institute

2018 Summer Program:
Medlytics

Program Overview

Data mining and machine learning have become ubiquitous in the age of "big data," and for good reason: advanced learning algorithms take advantage of ever-growing compute capacity and vast amounts of data to solve complex problems that can often meet or exceed human ability. These techniques are being embraced in nearly every sector, including financial trading, cybersecurity, entertainment, advertising, autonomous vehicles, and, of course, health and medicine. The increasing adoption of electronic health records, mobile health apps, and wearable technologies continues to generate troves of rich, real-time, high-resolution data. These data are now being used to train algorithms to help physicians build prognostic models, conduct medical image analysis, and improve diagnostic accuracy.

In 2018, the new BWSI Medlytics program will offer students the opportunity to explore the exciting intersection of data science and medicine. The program consists of two components: (1) online course from January to May 2018, open to all interested and committed students, and (2) a four-week summer program at MIT campus in Cambridge, MA for a group of 20–25 students from July 9–August 5, 2018. The online course will help students build a solid foundation in the fundamentals of probability and statistics, and provide an introduction to coding and machine learning techniques through a series of online teaching modules. During the summer, students will work in groups alongside Cambridge-area clinicians and data scientists to gain hands-on experience applying advanced machine learning and data mining to solve real-world medical challenges.

Online Course
The online component for the BWSI Medlytics course contains important introductory material to provide students with the background required to successfully complete the four-week summer course.   In addition to the introductory material, the online course will expose students to real-world data and machine learning techniques, and introduce some of the challenges and opportunities of combining the two.

Introduction and Background
- Perspectives on the challenges of working with medical data
- Probability and statistics
- Introduction to coding: Python, Git, Jupyter

Data Science for Health and Medicine
- Defining a patient cohort
- Correlation and regression; noise vs. outliers
- Beginner machine learning: supervised and unsupervised algorithms
- Introduction to time-series data analysis
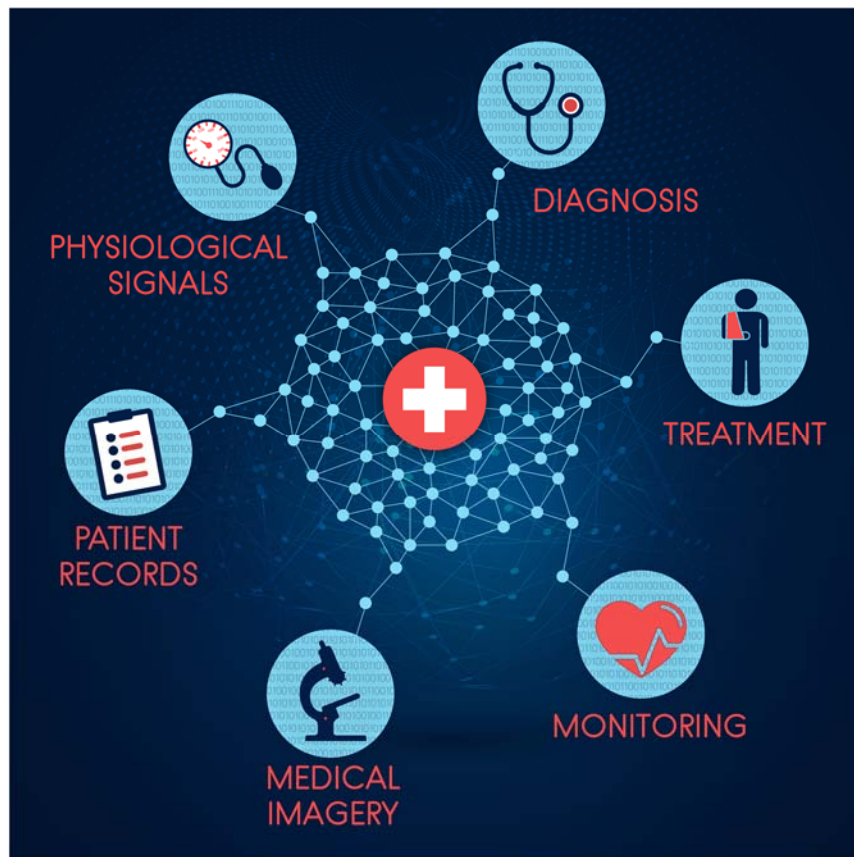
Summer Course

The four-week summer component of Medlytics will take a deep dive into the application of data analytics to physiological signals and time-series data. Daily course material, case studies, guest lectures, and small-group projects will expose students to challenges in signals analysis, and some state-of-the-art machine learning solutions. Boston-area clinicians and data scientists will mentor students as they compete in weekly challenges and participate in a final capstone project from concept proposal to live demonstration.

The following is a rough outline for the summer course:

Week 1: "First do no harm" (Introduction to Diagnostic Research and Signals Processing)

- IRB (CITI "Data or Specimens Only Research" course)
- Research questions, hypotheses and objectives: the FINER criteria
- Intro to signals processing (sampling, filtering, FFTs)
- Review and introduction to clinical time-series data
- Clinical Data Challenge 1: Noninvasive Fetal ECG

Week 2: "There is art to medicine as well as science" (Introduction to Machine Learning)

- Models and metrics; sensitivity and specificity
- Feature extraction
- Beginner/Intermediate machine learning (clustering, kNN, SVM)
- Machine learning on time-series data
- Clinical Data Challenge 2: Reducing False Arrhythmia Alarms

### Week 3: "I will not be ashamed to say 'I know not'" (Advanced Data Analytics)

- Artificial neural networks for advanced signals processing
- Working with open source deep-learning tools
- Clinical Data Challenge 3: Classification of Fundamental Heart Sounds

Week 4: "Look for a path to a cure" (Capstone Project)

In the final week of the course, students will work in teams with Boston-area clinicians to propose, build, and demonstrate a mobile health application prototype, leveraging the lessons learned from weeks 1–3.

MIT Beaver Works Summer Institute
2018 Summer Program:
Embedded Security and Hardware Hacking
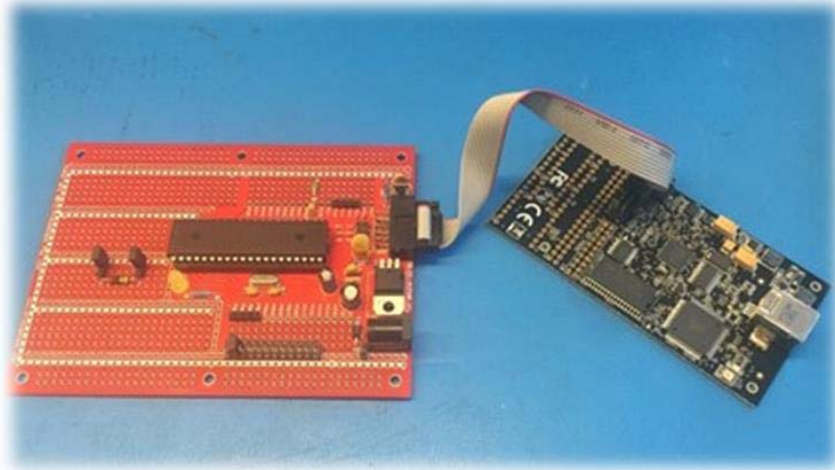
Program Overview

Most of us are aware of our reliance on computers throughout our everyday lives, but what we typically think of as computers (from the servers that run our favorite websites, to our laptops and smartphones) are only the tip of the iceberg. Hidden just beneath the surface is a substantial and diverse group of computers referred to as embedded systems. Although the concept may be unfamiliar to many, embedded systems are pervasive and have existed for decades. They commonly work within larger pieces of technology, performing specific tasks, such as operating one element of a car, medical device, aircraft, or even a musical instrument. Their security affects the security of the larger system. And they are being hacked!

This program consists of two components: an online course from January to May open to all interested students, and a four-week summer program at MIT from July 9 to August 5 for a select group of students.

The online course will introduce the students to several security topics with a focus on threats that are especially concerning for embedded systems. These topics include: embedded software security, cryptographic protocol attacks, JTAG and UART probing, side-channel analysis and fault-injection, and hardware Trojans. This background will help prepare students for the summer course, during which they will perform security assessments of multiple implementations of an embedded system: a wireless home door lock. Teams will compete to see who can find and fix the most security flaws in these systems.

Online Course

The online component for the Embedded Security and hardware hacking course contains important introductory material to provide students with the background required to successfully complete the four-week summer course. A virtual machine image is provided for students to download and use on their own computers, with necessary tools preinstalled, so that they can work through both the introductory and more advanced topics.

The online course will consist of the following modules:
- Introduction to hardware hacking
- Embedded software exploitation
- Applied cryptography
- Side-channel analysis
- Fault-injection
- Hardware Trojans

Summer Course

The four-week summer program is based on the MITRE 2016 Collegiate eCTF, which challenged teams of undergraduate and graduate students to design a secure system for an Internet-enabled home door lock with two-factor authentication. BWSI students will examine the submissions from real college teams and hunt for security flaws. The course will consist of a mix of lectures and hands-on projects that reinforce and apply the material. The detailed topics for each week are listed below:

Week 1: Reconnaissance
- The BeagleBoneBlack ARM development board
- Introduction to the target designs

Week 2: Red-team
- Techniques for security assessments
- Thinking like an attacker

Week 3 and 4: Hack!
- Teams will compete to see who can score the most points – earned by capturing virtual "flags", by demonstrating flaws in the target systems, and by fixing the flaws to secure the system.

MIT Beaver Works Summer Institute
2018 Summer Program:
Build a Cubesat
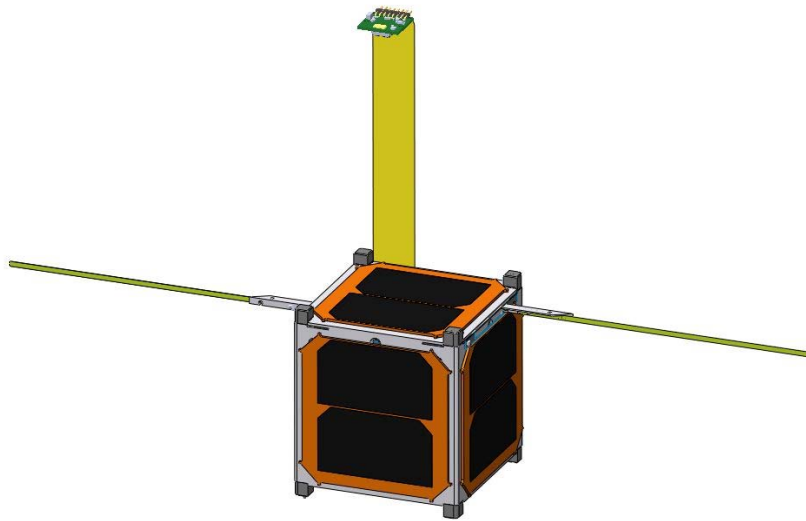
Program Overview

In 2018, a new BWSI course dedicated to building, testing, and flying a Cubesat will offer this access to space for a new group of students. Based around a 1U Cubesat (10 cm x 10 cm x 10 cm), the four-week course will guide the class through the design trades, assembly, and testing of a Cubesat with an imaging payload. The program will consist of two components. The first is a series of on-line courses teaching the basics of satellite development coupled with computer driven exercises that will allow the class to perform key design trades for the mission involving communication, power generation and usage, size, mass, and performance. The four-week summer proram will review the key points from the online course and add in lessons on how to handle and test hardware before heading into the lab to assemble and test a working satellite. During the summer course, students will work with Lincoln Laboratory staff and MIT graduate students to gain hands-on experience in building a space system. The satellite will be launched at the first possible opportunity, allowing students to track and observe their working space system.

The progression of miniature electronics coupled with the availability of launch rideshares provides access to space for a wide range of organizations that weren't able to dream of such capability 20 years ago.   The advent of the Cubesat standard by Bob Twiggs and Jordi Puig-Suari in 1999 opened up real, achievable access to space for student projects that allows for hands-on development experience for the next generation of scientists and engineers.

Online Course
The online component for the BWSI Cubesat course contains important introductory material to provide students with the background required to successfully complete the four-week

summer course. In addition to the introductory material, the online course will expose students to real-world trades that occur when designing systems for space.

Introduction and Prerequisites
- Why we go to space?
- Basics of rockets and orbital dynamics (using Systems Toolkit)
- Spacecraft subsystems

Satellite Design Work
- Spacecraft systems design trades
- Power systems
- Communications systems
- Payloads and camera performance

Summer Course
The four-week summer component of BWSI Cubesat will focus in the lab on building and testing spacecraft hardware. Daily lectures will review the basics with the students, and guest lectures on key spacecraft systems will be given. In the lab, students will split into subsystem teams to get hands-on exposure to hardware testing, assembly, and environmental screening. Students will be mentored by Lincoln Laboratory staff, and MIT faculty and graduate students.

The following is a rough outline for the summer course:
Week 1: "Space, The Final Frontier" Hardware Basics and Systems Engineering
- Space systems 101
- Basic hardware safety and handling
- Software fundamentals

Week 2: Spacecraft Subsystems
- Testing and assembly of all subsystems
- Payloads and camera performance
- Communication and power
- Software, the glue that holds it all together

Week 3: "Houston We Have A Problem" Making It All Work Together
- Subsystem integration
- System and software testing
- Debugging and testing a flight system

Week 4: "Shake and Bake" Environmental Test and Simulation
- Final functional testing
- Launch simulation via servo-hydraulic test system
- Vacuum and thermal performance

Must be a U.S. citizen to participate in this course.

![MIT | BEAVER WORKS — Lincoln Laboratory | School of Engineering]

MIT Beaver Works Summer Institute

2018 Summer Program:
Unmanned Air System-Synthetic Aperture Radar

Program Overview

The recent explosion of unmanned air vehicle (UAV) technology coupled with the miniaturization of electronics opens the door to countless applications and missions. UAVs can provide unparalleled views at sporting events, images of structures which are not safely accessible to construction workers, and scenic aerial photography, all using low-cost camera technology. One can also envision many applications of small UAV-based radar solutions, ranging from day/night autonomous tracking of objects of interest in all–weather conditions to change detection using radar imaging techniques to search and rescue.

In 2018, the BWSI Unmanned Air System – Synthetic Aperture Radar (UAS-SAR) program will offer students the opportunity to explore the field of radar imaging by building and flying a radar on a small UAS and using it to image objects around campus. The program consists of two components: (1) online course from January to May 2018, open to all interested and committed students, and (2) a four-week summer program at MIT campus for a small group of students from July 9–August 5, 2018. The online course will help students build a solid foundation in the fundamentals of UAV flight; linear algebra and coordinate transformations; the fundamentals of radar including the Doppler effect; and an introduction to the software tools used in radar processing. During the summer, students will work in small groups alongside mentors to gain hands-on experience building, integrating, and processing data from a radar to image objects around campus.

Online Course
The online component for the BWSI UAS-SAR course contains important introductory material to provide students with the background required to successfully complete the four-week summer course. In addition to the introductory material, the online course will expose students to real-world radar data and UAV motion properties.

Introduction and Prerequisites
- Introduction to vectors
- Linear transformations

- Matrices and matrix manipulation
- Software programming for data acquisition and signal processing

Radar Systems and UAV Technology
- Flight dynamics
- Fundamentals of propagation and radar range equation
- Doppler effect and Doppler processing
- Introduction to radar imaging

Summer Course

The four-week summer component of UAS-SAR will feature a mix of lectures from radar experts, and hands-on laboratories with mini-capstone milestones at the end of each week. Daily lectures will reinforce basic radar concepts and dive deep into the principles behind radar imaging. Students will learn to interpret radar imagery, assess image quality, and understand what features are most clearly imaged.

Week 1: Let's Build a Radar
Students will build a functioning radar in steps, measuring terms in the radar equation, and at the end of the week complete the radar and data acquisition system.

Week 2: Let's Build an Image
Students will begin to generate radar images using step-stare synthetic aperture radar mode on a rail system for very controlled motion effects. Students will learn to compensate for platform motion and generate their first image of a corner reflector.

Week 3: Up, Up, and Away
During the third week, students will integrate the radar system onto a small UAV. They will measure the UAV dynamics, and apply motion compensation to prepare for the final imaging challenge.

Week 4: Best Image Challenge
Students will select objects around campus to image, in hopes of becoming the first–ever BWSI Radar Imagery Champion.

2018 Summer Program:
Unreliable Media

https://xkcd.com/1283/

Program Overview

Unreliable media and "Fake News" are becoming a part of everyday life. The internet can be the wild west, who and why should you trust someone or a piece of content? Many international efforts are focused on automated fact checking developed through stance detection, as in the Fake News Challenge (http://www.fakenewschallenge.org/). The program's goal is for participants to build end-to-end systems to detect unreliable media content based on multimodal features. Students will be exposed to three main components: 1) feature extraction from raw data, 2) classification via machine learning techniques, and 3) decision fusion from multiple classifier scores. The program will explore tools that analyze media style by exploiting text, images, and cyber features.

In 2018, the new BWSI Unreliable Media program will offer students the opportunity to explore the exciting intersection of data science and the media. The program consists of two components: (1) online course from January to May 2018, open to all interested and committed students; and (2) a four-week summer program at MIT campus in Cambridge, MA. During the course, the students will be trained to understand the basics of Python, Git, natural language processing, machine learning, and image processing through a series of online teaching modules. Students will explore datasets ranging from politics to sports that are both functional and fun. By participating in the online and/or onsite portion of the program, students will develop experience in an area of data science that is poised to play a critical role in understanding our world.

Online Course
Prior to the summer course at MIT campus, students will be required to complete an online course that contains important introductory material. The online course will give the students

the strong foundation required to successfully complete the four-week summer course. In addition to foundational introductory material, the online course includes discussion of different use cases and exposes students to real world challenges and applications of the coursework.

Introduction and Prerequisites
- Getting started with Python
- Git & GitHub management
- Machine learning perspectives

Data Science
- Advanced NumPy
- Simple image classification
- Introduction to Web Services

Natural Language Processing
- Using StanfordNLP
- Text metrics and assumptions
- Statistical models

Summer Course

The four-week summer component aims to guide students through the processing of designing experiments to evaluate primarily text-based content. Daily course material, case studies, guest lectures, and small-group projects will expose students to challenges across technical domains.

The following is a rough outline for the summer course:

Week 1: Foundation
- Python/NumPy/Github review
- Review of machine learning concepts
- Research questions, hypotheses and objectives
- Working with open source tools and data
- Models and metrics; sensitivity and specificity
- Structured vs. unstructured data

Week 2: Text Processing
- Feature extraction and preprocessing
- Beginner/Intermediate machine learning (clustering, kNN, SVM)
- Generative statistical models

Week 3: "Not Text" Processing
- Feature extraction and preprocessing
- Image analysis
- Metadata analysis

Week 4: Challenges and Use Case
- Apply what you learned and determine what is and isn't reliable content!

BWSI Online Program Application Process

The Beaver Works Summer Institute is pleased to announce that we are expanding our program offerings for summer 2018. The following programs will be offered:

- Autonomous RACECAR Grand Prix
- Hacking a 3D Printer
- Medlytics
- Build a Cubesat
- Unreliable Media

- Autonomous Air Vehicle Racing
- Cog*Works: Build Your Own Cognitive Assistant
- Embedded Security and Hardware Hacking
- Unmanned Air System–Synthetic Aperture Radar

To apply to one of these summer programs, you must complete the BWSI Online Education Program, designed to prepare students for the technically rigorous BWSI summer programs. To participate in the online course, a student must submit the following:

1. A nomination by a school technical point of contact (POC), typically a STEM teacher or school administrator familiar with the student's schoolwork and technical abilities. The nomination form for the teacher/recommender can be found at
   https://mit-bwsi.formstack.com/forms/mit_online_course_request

2. The application form for the student will be sent to them once the request comes in from the teacher/recommender.

   Once the application is approved, the student will receive an email containing a user ID and password as well as instructions on how to access the online course website.

Teachers, prior BWSI students, and teaching assistants (TAs) can also apply for online course access by using the same BWSI online course request link and filling out the form.

BWSI Summer Program Application Process

Application for the BWSI Summer Program is separate from the online course application. The Summer Program application will be available Mid-March 2018, with decisions expected in April 2018. The selection criteria for the Summer Program include, but are not limited to,

1. Demonstrated technical ability (determined through recommendation by school official and other supporting information, such as test scores, completed coursework, and grades collected in the application).

2. Demonstrated commitment to extracurricular learning via participation and completion of the online course (participation and progress are tracked within the online course educational modules).

Students must make significant progress in the online course by Summer Program application to ensure that they are ready and well prepared for participation in the BWSI programs. Students may participate in one or more of the online courses to determine which they are interested in, but note that the online courses are time-intensive, and we suggest down selecting to a single course as early as possible.

Beaver Works Summer Institute (BWSI) RACECAR Remote/Travel Team Participation Guidelines and Recommendations

Four remote teams, including two from Mexico, completed the BWSI 2017 RACECAR program. The teams were able to follow the same curriculum as the MIT class, travel to Cambridge, and successfully participate as peers in the final challenge events at MIT. On the basis of their experiences, we have formulated guidelines and recommendations for teams who might be interested in participating remotely.   This option may be beneficial to international schools; and to schools contemplating adopting or offering the RACECAR program in their own curriculum, increasing the number of opportunities for their students to participate in the program. We assume a certain level of familiarity with the overall program and RACECAR curriculum in particular, in the descriptions below. It may also be helpful to review the BWSI Program Brochure and Admission Procedures materials for additional background and context.

Overview

Your students can be prepared to participate in the BWSI RACECAR course by completing the prerequisite online content we provide and require of all prospective applicants. When the summer program begins, students are able to follow along with the summer program "live" by using the same content we teach in our classroom. The final Grand Prix track layout and design of special features intended to technically challenge and demonstrate the student teams' skills is revealed at the start of the fourth week of the RACECAR course. The entire fourth week is a "build week" during which the teams design, build, integrate, and test their systems and component implementations. We have instructors, mentors, and coaches available to support teams throughout the process by answering and asking questions, observing team interactions, and offering helpful tips (without providing solutions). Remote teams are also welcome to attend during this week to build their implementation, interact with other students, observe other teams, and benefit from our support. All teams participate in the weekend Final Challenge Demonstration events.

Online Preparation

New and updated content is made available during January in our online EdX course that all prospective students are required to complete for admission or participation in the summer program. The course is organized into topical modules that cover technical subjects of interest and then develop skills needed to work with the RACECAR. The course is intended to ensure all students arrive with a common baseline set of skills and exposure to technical topics that we can build upon in the summer program.

The online content enables students to begin the learning process even before they have a RACECAR vehicle available. Instructions are provided to install, operate, and program a model RACECAR in a simulated environment using the same tools and interfaces as the physical vehicle. We include sensor simulations and model "worlds" of previous BWSI final challenge tracks and others that have been used in MIT courses.

Prior course content, much of which will be reused remains available for access by anyone with registered credentials at http://bwsix.mit.edu/. We work through single designated points of contact at each school to set up and verify access to this site for local instructors and individual students.

Summer Program Curriculum

Once the summer program begins, we release the in-class content as it is delivered in the classroom. To facilitate that process in BWSI 2017, we created a BWSI 2017 module in our online course and updated and added links to the content for lectures, labs, and demonstration challenges in the weekly topic sections, each day. This was the same mechanism used to release the content to the MIT BWSI students to ensure everyone whether local or remote, received identical material at the same time. The content is primarily in the form of links to streaming and recorded lectures, lecture slides and notes, hands-on lab handouts, sample code snippets, and end-of-week challenge descriptions from the 2017 program, which are still available for reference.

It is essential that remote/travel teams have local instructional and mentoring support for the preliminary on-line preparation, and hardware/software build/installation process, especially during the summer program itself. We recommend that prospective instructors and mentors go through the online course themselves and/or are otherwise prepared to support their students in understanding the content. Some schools have established relationships with MIT or a local university with departments that have students who may be recruited for internships as effective in-class or afterschool mentors for their teams.

Build Week and Final Event Participation

We recommend teams arrive at least three days before the Final Challenge event and are welcome to spend the entire "build week" with us. Early arrival ensures teams have sufficient time and opportunity to become acclimated, verify their hardware operation, and build/design/test their software implementation against the specific technical challenges under representative conditions that they will encounter in the final event. This week is very intensive for all teams, and while we generally have an instructor, mentor, or coach for every team, demands on their time and attention are high.

Guidelines and Requirements

These requirements are intended to ensure that all teams have the same working hardware configuration, software architecture with required capabilities, and level of preparedness needed to succeed in the build week and Final Challenge event.

Your student team(s) must build or buy a RACECAR that matches specifications of the summer program vehicle. Those specifications (bill of materials, laser cutting files, and assembly guide) are publicly available and the parts cost of a typical build is approximately $5000. Assembly time varies with experience but is typically on the order of 8 hours for someone with basic mechanical and soldering skills using the guide we provide.

The proper operation of the vehicle must be demonstrated using the baseline software provided for the summer program before arriving at MIT. We can only provide very limited diagnostic and repair support for vehicles. We recommend teams bring a selected set of spare parts and a tool kit with them that reflects on their past experience building, operating, and maintaining their own RACECAR.

Logistics

Housing must be arranged for your students. Area hotels are available and home stay options may be possible if family relatives or sponsors live in the local area. We can provide no support for finding or making such arrangements or any transportation required to attend the program for remote/travel teams.

For international teams from institutions who participate in the MIT MISTI program, you may already have a MISTI program point of contact who could help with logistics and possibly recruit mentors from the MIT community to support your teams.

We do not arrange for visas required for travel, but can supply or sign documentation that explains the purpose for the trip.