Proposed Syllabus for CS 7626 Introduction to Behavioral Imaging

This course will provide an introduction to Behavioral Imaging, a new research field which encompasses the measurement, modeling, analysis, and visualization of behaviors from multi-modal sensor data to support health applications. It is tailored for graduate students who are interested in this emerging field. The course is designed to provide:

- A broad introduction to research questions in Behavioral Imaging (BI)
- An in-depth understanding of the key technologies for BI
- Hands-on experience in working with relevant sensor data (video, audio, wearable)
- An overview of the psychology literature relating to behavior from a computational perspective

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Background

Beginning in infancy, individuals acquire the social, communicative, and cognitive skills which are vital for a healthy and productive life, through face-to-face interactions with caregivers and peers. However, children with developmental conditions such as autism face great challenges in acquiring these skills, resulting in substantial lifetime risks. A major challenge in screening, diagnosing, and treating developmental disorders and childhood mental illness is the lack of well-defined biomarkers which could provide objective, easily-assayed measures of risk, as well as outcome measures for assessing the effectiveness of treatment. In the case of conditions such as autism, and many other developmental conditions, the gold standard for care is the direct observation and assessment of a child's behavior by a trained professional, an approach which does not easily scale to the population in need. As a result, there is a great need to develop behavioral biomarkers which can be automatically and objectively measured through advances in sensing and computing. We refer to the use of sensors and machine learning methods to measure and model behavior from data as *Behavioral Imaging* [1], making an analogy to the field of medical imaging which transformed medical practice and clinical care over the past century by enabling the objective, quantitative assessment of states of health and disease. The goal of behavioral imaging is to bring about a similar transformation in the assessment and treatment of behavioral conditions and disorders.

Moving beyond developmental conditions and mental illness, the automated measurement of behavior and physiology can also play an important role in the prevention and treatment of medical (health) conditions. For example, in chronic health conditions resulting from smoking, alcohol and drug abuse, physical inactivity, and poor diet, the behaviors and habits of the participant play a key role in determining their health outcomes. While decades of research in behavior change have identified treatment and intervention strategies, a major barrier is the inability to reliably measure health-related behaviors, particularly in naturalistic (field) conditions. The current gold standard is self-report, which is known to be inaccurate and is also burdensome for participants. Once again there is a great need for objective, automatic, and reliable assessments of behavior and physiology from body-worn devices which could provide a continuous-monitoring capability throughout daily life. Mobile devices also create the possibility of delivering behavioral interventions in an automated, scalable, and personalized manner.

Advances in sensing, including extended battery lifetimes and smaller form factors, make it increasingly feasible to deploy suites of sensors to enable the objective measurement of behavior and physiology. This trend is manifest in the growth of consumer devices ranging from wireless video baby monitors to activity and fitness trackers such as the Fitbit. At the same time, advances in machine learning have made it possible to automatically analyze multimodal streams of sensor data and extract actionable information, creating the possibility for real-time sensor-triggered interventions to support behavior change. The field of *Mobile Health* (mHealth) [2] addresses the use of mobile devices to measure behavioral and physiological processes and provide interventions via mobile platforms. While this community is defined by an emphasis on mobile sensors and adult populations, it is closely-connected to our broader goals in behavioral imaging.

[1] Rehg, J. M., Rozga, A., Abowd, G. D., & Goodwin, M. S. (2014). Behavioral imaging and autism. *IEEE Pervasive Computing*, 13(2), 84–87. http://doi.org/10.1109/MPRV.2014.23

[2] Rehg, J. M., Murphy, S., & Kumar, S. (2017). *Mobile Health: Sensors, Analytic Methods, and Applications*. Springer. In press.

Textbook

We will utilize a newly-published edited volume [2] along with recommended readings.

Prerequisites

This class will be self-contained with respect to the core concepts and class material. Background material will be provided, so there are no subject-matter prerequisites. Some of the projects will require familiarity with either Python or Matlab. A basic understanding of machine learning and signal processing will be useful but not required.

Learning Objectives

The goal of this course is to enable students to

- Become familiar with the computational tools and models which define the state-of-the-art in estimating information about people and their behaviors from multimodal streams of sensor data, including video, audio, and accelerometer/gyro.
- Gain exposure to the behavioral dimension of health and the role of technology in enabling a large-scale data-driven approach to behavioral medicine and the diagnosis and treatment of mental health conditions.
- Obtain hands-on experience working with sensor data and developing and validating analysis methods for processing sensor data and dealing with real-world issues such as sensor noise, signal drop-out, and synchronization.

Organization

The class will consist of both lectures and discussions of papers drawn from the relevant literature which are reviewed and critiqued by teams of students. Each student will join a discussion group at the start of the term. Each discussion group will choose a discussion topic consisting of 1-2 papers to review from a predefined set of choices based on the syllabus (some customization is possible where student groups have specific interests). Each discussion group will have a specific deadline during the term for completing their review, posting a critique to Piazza, and facilitating a discussion with the class. All students are required to read the key paper from each discussion topic by the deadline and participate in a discussion of the topic on Piazza. The topic presentation and discussion schedule is aligned with the major lecture units, so that students will be reading and discussing papers which are relevant to the lectures (and supplement them) throughout the term. Each discussion group will have the opportunity to present their findings and a summary of the discussions from Piazza to the class during part of the lecture period. In addition to the review and discussion of papers from the literature, students are also required to complete two predefined projects representing two major BI technologies. Students will have the option to work either singly or in pairs to complete the projects.

Grading

- Participation in a discussion group: 15%
- Participation in Piazza discussions of the readings throughout the term: 15%
- Two Projects: 50% (25% x 2)
- Final Exam: 20%

There will be two projects that will give you hands-on experience in analyzing a particular type of behavioral signal and extracting relevant behavioral information. We will provide you with some existing dataset and analysis tools in each case.

Project 1: First Person Vision

For this project, each team will be provided with video dataset collected with a wearable camera during a face-to-face social interaction. You will make use of the IntraFace face analysis toolkit to perform analysis of the video. It provides the capability to detect faces and track facial landmarks, such as eyes, mouth, etc. More details will be provided in the project writeup.

Project 2: IMU Activity Recognition

For this project, each team will be issued a dataset of IMU signals (accelerometers/gyroscopes) recorded during periods of daily life activities. The dataset will contain some annotations of activities of interest. The goal is design and implement an analysis approach for recognizing a behavior in the field, such as drinking, eating, physical activity, etc. More details will be provided in the writeup.

Final Exam

The final exam will be open book, open notes and will cover all of the lecture material and paper readings. The exam will test your understanding of the theoretical and conceptual foundations of BI, in terms of both specific mathematical models and theories, as well as your ability to synthesize a broad range of topics technology, physiology, and behavioral science in discussing specific health applications.

Academic Integrity

Academic dishonesty will not be tolerated. This includes cheating, lying about course matters, plagiarism, or helping others commit a violation of the Honor Code. Plagiarism includes reproducing the words of others without both the use of quotation marks and citation. Students are reminded of the obligations and expectations associated with the Georgia Tech Academic Honor Code and Student Code of Conduct, available online at www.honor.gatech.edu.

Learning Accommodations

If needed, we will make classroom accommodations for students with documented disabilities. These accommodations must be arranged in advance and in accordance with the Office of Disability Services (http://disabilityservices.gatech.edu).

Excused Absence Policy

http://www.catalog.gatech.edu/rules/4/

Lecture Topics

- Introduction to Behavioral Imaging
    - Topics: Healthcare system, population health and epidemiology, biomarkers
- Developmental View of Behavior
    - Topics: Physical, social/emotional, and cognitive developmental processes, milestones and timelines, behavior assessment, modeling change over time, research methods
- Disorders of Development
    - Topics: Autism, joint attention and language, outcomes, screening and diagnosis, interventions and treatment, research methods
- First Person Vision
    - Topics: Overviews of computer vision and deep learning, egocentric cues, methods for object detection and activity recognition, egomotion estimation and localization
- Visual and Social Attention
    - Topics: Overview of neuroscience of attention, eye tracking technologies, social attention and its impairments, visual exposure and persuasion
- Facial Affect and Emotion
    - Topics: Face detection and tracking in video, FACS, expression analysis using holistic and landmark-based methods, links between affect, mood, and behavior
- Introduction to Audio Analysis and Signal Processing
    - Topics: Frequency domain, overview of Fourier transform and filtering, acoustic signal modeling, speech production in autism, LENA and the language environment
- Research Methods in Behavioral Science
    - Topics: Experiment design, overview of statistical inference, hypothesis testing, confidence intervals and effect size, power analysis
- Behavioral Interventions for Autism
    - Topics: Treatment approaches: ABA, ESDM, and play-based, assessing treatment outcomes, randomized controlled trials, comorbidities and pharmacological treatment
- Behavioral Medicine
    - Topics: Health-related behaviors, theory of behavior change, lifestyle and habits, substance dependence and abuse, risk factors, policy
- Physiology and the Autonomic Nervous System

  - Topics: Cardiopulmonary function, stress and arousal (challenge-threat model), sleep, circadian rhythms, physical activity, heart failure
- Introduction to time series analysis
  - Topics: State-space modeling and ARIMAX, frequency domain representations, forecasting and detection problems, hidden Markov models
- Measuring physiological and behavioral states via wearable sensors
  - Topics: IMU design and function, ECG, plethysmography, electrodermal activity, measuring stress, craving, and self-efficacy.
- Activity recognition from wearable sensors
  - Topics: IMU-based activity modeling and recognition of physical activity, eating, drinking, and smoking, sensor positioning, synchronization.
- Case Study of Mobile Stress Intervention
  - Topics: Just-in-time adaptive intervention (JITAI), microrandomization, EMA, intervention app, burden
- Platforms for Mobile Health
  - Topics: mCerebrum and MD2K Cloud architectures, battery life and communication, addressing security, privacy, and provenance, integration with clinical data sources