# CREU 2016-2017 Final Report: Automated Abnormal Behavior Detection in Crowds from Multi-Camera Videos

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## I. Goals and Purpose

In general, remote sensing camera systems and object-tracking algorithms are rich in problems and challenges. Such systems, however, can provide valuable information in desired regions of interest, while assisting humans and possibly protecting from an unnecessary direct engagement. In many cases, it is desirable to detect and track individuals and other stationary and dynamic objects across these areas of interest from live video to understand social dynamics taking place. The accurate detection and tracking of humans from a camera system poses an interesting problem, given the processing needed to detect unique human characteristics and behaviors. The significance of this problem and opportunity is that once the camera can detect and track individuals, it would then be able to provide 'tracks' data in real-time, keeping a continuous record of a person of interest's motion path. One would then have a full picture of all movements that have taken place in a given area.

Our main research goal of this proposal was to develop and demonstrate algorithms capable of real-time human detection in an area of interest from standalone video processing systems, as well as extracting simple (linear time and movement) tracks data. Our research will serve as a building block for further research on creating complex tracks data and the ability to understand a crowd's social dynamics. Several objectives were specified in order to support the main goal as well as to engage us in a variety of activities to help us understand the challenges of real-world research. Our list of specific objectives was as follows:

(1) Study the current video collection systems described by the literature.
(2) Identify the components and install software for the experimental system.
(3) Experiment with algorithms capable of real-time human detection.
(4) Develop and demonstrate algorithms for CV controlling autonomous robot movement.
(5) Gain deeper understanding computer vision problems and applications by participating in conferences.
(6) Engage the community in our research.
(7) Participate in other supporting activities.

## II. Related Work

Machine Learning (ML) and Computer Vision (CV), within Artificial Intelligence (AI) are undergoing dramatic changes with the discovery of new approaches almost every day. This rapid change is being brought about by big data and better understanding of existing approaches like artificial neural networks and how they can take advantage of fast and parallel hardware and get trained on extremely high amounts of data (Schmidhuber, J., 2015). There is an intensification of research in AI for number of commercial applications. As an example, Google Research reported improvements in pedestrian detection (Angelova et. al, 2015). This is an important research topic in CV area leading to recognizing and tracking individuals resulting in crowd behavior analysis.

One group used an analogy between of crowd movement and physic theory of fluid mechanics which allowed them to create a correlation to crowd behavioral features (Kok et. al., 2015). One of the interesting aspects of their research is the emphasis on swarm behavior. Organisms that swarm have some way of communicating locally that helps the swarm as a group, while not having any intelligence coordinating it externally. They used the example of a school of fish avoiding predators. Some individual fish do get eaten, but by communicating with their neighbors, the rest of the swarm is able avoid immediate danger. Research suggests that human behavior in crowds share common traits with other organisms that practice swarm behaviors. In many cases, individuals traveling within a crowd often follow the general direction which allows no disruption in the crowd movement. Even in the absence of verbal communication between individuals in a crowd, humans instinctively move in the same direction and follow the crowd form. This can be seen in individuals in a crowd moving in different directions. Individuals unconsciously move into groups with similar movement plans. By moving into their preferred group, each group of individuals is able to avoid collision with one another and arrive at their destination.

## III. Process

### Identify the components and install software for the experimental system.

Initially we familiarized ourselves with cameras and software to collect both the still pictures and videos. After we became acquainted with the platform, we began collecting video from the camera systems. This required a series of parameters to bind the problem, including videos from multiple heights, multiple modes of operation, and varying scenes with different groups of present humans. This was a critical step in creating a corpus of data to be analyzed.

The second activity was to install software for the experimental system to process video and use human detection computational models. In the process, we installed Ubuntu and OpenCV libraries. We also installed Anaconda under Windows 10 and OpenCV libraries. The OpenCV contained individual software library modules to detect which video frames contained humans.

We have developed several software components in an attempt to create a software framework that supports current and future activities. Once completely developed this framework will provide future undergraduate researchers with the preconfigured hardware and software platform for further CV experiments. Our experience with Ubuntu proved to be challenging and as a result we decided to restrict our framework to the Windows environment. The last version of our framework includes workstations with GPUs that have open source software libraries based on complete Anaconda package installation with OpenCV library.

**Experiment with algorithms capable of real-time human detection.**

Initially, models based on individual software library modules were used to detect which video frames contained humans. In this research, we engaged in experiments with 9 approaches for real time human detection. In the first two approaches, we attempted to train our own machine-learning algorithm using a HAAR cascade (Viola and Jones, 2001) and Local Binary Patterns (Ahonen et. al., 2004) (LBP) as image features. We discovered that these two methods have potential, but require vastly larger datasets than we possess. The next several approaches that we worked on involved using machine-learning algorithms that were already created and trained using enormous datasets, and available for public use. The first of these was the Facebook software suite, Multipathnet with DeepFace and SharpMask. (Zagoruyko, 2016). The other six are Visual Tracking with Online Multiple Instance Learning (Babenko et. al. 2008)(MIL), Real-time tracking via on-line boosting (Grabner et. al., 2006) (BOOSTING), Kernelized Correlation Filters (Henriques et. al., 2015) (KCF), Tracking-Learning-Detection (Kalal et. al., 2012) (TLD), Forward-Backward Error: Automatic Detection of Tracking Failures (Kalal et. al, 2010) (MEDIANFLOW) and Learning to Track at 100 FPS with Deep Regression Networks (Held et. al., 2016).

**Develop and demonstrate algorithms for Computer Vision controlling autonomous robot movement.**

Another important research activity was related to using computer vision for control of autonomous robots as required by participation in the swarm robotics group. This group was created to compete in the NASA Swarmathon at NASA Kennedy Space Center that was held in April. Most of our CREU team was recruited to participate in the swarm robot competition, so we all attended several NASA webinars, one of which was the Swarmathon Tech Talk, where we could talk to the NASA engineers about our robots and the code that we wrote. In the process of working with the swarm robots, we learned how to troubleshoot the hardware as well as the software. One particular task involved reinitializing the robot's inertial measurement unit (IMU). We developed a spiral search algorithm, where the robot starts near the home base, and spirals out from there, looking for targets to return to a collection plate. Our algorithm also included site fidelity, in that once it found a target rich source, it would remember the location of the targets and return to that location after dropping its current target at the collection plate.

**Gain deeper understanding computer vision problems and applications by participating in conferences**

We were given an opportunity to gain deeper understanding computer vision problems and applications by participating in multiple conferences. Several members of our team attended conferences through generous scholarships awarded by CRA-W and a local program called Research for Scientific Enhancement (RISE) sponsored by the National Institutes of Health/ National Institutes of General Medical Sciences (NIH/ NIGMS). Our team created and presented a poster of our research, "Automated Abnormal Behavior Detection in Crowds from Multi-Camera Videos," at the State of North Carolina Undergraduate Research and Creativity Symposium (SNCURCS) in November 2016. In that same month, Mr. Cooper attended the Annual Biomedical Research Conference for Minority Students(ABRCMS), which was held in Tampa, Florida. Ms. Spooner obtained a travel scholarship from CRA-W to attend the High-Performance Computing Workshop in early February 2017. This workshop was held in Albuquerque, New Mexico. She was also selected for a travel scholarship from CRA-W to attend the AAAI diversity in AI workshop and general conference in late February, which was held in San Francisco, CA. In March 2017, Mr. Cooper obtained a scholarship to attend the Society for Industrial and Applied Mathematics(SIAM) Conference on Computational Science and Engineering (SIAM CSE), which was held in Atlanta, Georgia. He was able to tour the Google Fiber Lab, and attended a meeting with the assigned conference mentor where the students were paired with mentors from industry.

**Engage the community in our research**

Research that is not shared with others is not useful, so our team also engaged in several community service opportunities where we were able to disseminate our research to various groups. One of these opportunities was provided by the Swarmathon competition. As part of our participation in the competition, we were also able to mentor students at two high schools, Terry Sandford and Jack Britt High Schools, in Fayetteville, North Carolina. The goal of this program is to get more high school students involved in computer science and motivate them to major in computer science in college.

The students were given modules that were created in a language called Netlogo. They had to write code to simulate the rovers collecting rocks on the surface of Mars and return the rocks to a collection zone. Each module included different approaches to collecting the rocks. We held several workshops to assist the students in learning Netlogo. Since we were not familiar with it, we were also required to learn Netlogo.

We also participated in a science demonstration with about 200 local elementary school children. We gave a demonstration of our current research. We explained how our research relates to projects that they might be familiar with. We were quite impressed with the questions that these kids asked.

**Participate in other supporting activities**

We were also engaged in various other activities that enhanced our research experience. Mr. Gibson was chosen to be a contestant of the ACM International Collegiate Programming Contest. This annual contest was sponsored by IBM. Teams of students around the district compete to demonstrate their programming skills.

We also had the opportunity to attend several computer science seminars at our university. In particular, one of seminar involved the keynote speaker Dr. Wayne Patterson, a computer science professor from Howard University. He talked about behavioral cybersecurity that relates to our research about anomalous behaviors.

Our team member, Lee Gibson, was also awarded a travel scholarship to attend the Pennsylvania State University STEM Open House. During this open house, he was exposed to many research areas that are pursued by students at Pennsylvania State University.

## IV. Results and Discussion

The software framework that we created allowed us to achieve automatic human recognition in a video stream. We were able to quantify precision of human


*Figure 1*

recognition and tracking and compare each of the methods. The experiments allowed us to determine limitations to how well humans were detected by each model. After analyzing limitations, we worked on optimizing human detection models with respect to a specific environment.

Figure 1 is a screenshot of the MIL method applied to one of the video samples. We observed a delay in identifying a person of approximately 20 frames. The explanation is that the ML model is trained on a complete person, but the first frames from the video contained only fragments of a person, or no person at all. Eventually the model worked fairly well at recognizing and following the person throughout most of the video. It did seem to have serious issues with occlusion, though. In this case, it is necessary to add building blocks to deal with occlusion and other crowd recognition related challenges.

As a result of development of algorithms for CV controlling autonomous robot movement we accomplished the task that our robots pick up a fair number of cubes. They also returned them close to collection plate. However, they were not always dropped off at the actual collection plate, which is a localization problem. A better method for detecting the collection plate will need to be found for the next competition.

One issue we had was that one of the robot would get itself stuck in the collection plate and would be unable to get out. The robots are programmed to treat the April tags on the collection plate like an obstacle to be avoided unless they actively have a cube in their gripper. After they drop it, they're supposed to leave the area. If they cross that barrier for any other reason, they become trapped inside believing that there is a barrier on all sides. When this happens, the robot will turn around constantly, looking for a way out. Unfortunately, while they are doing that, they knock any previously accumulated block out of the collection zone, which decreases the score of the unfortunate team. We noticed this behavior in both heats that we participated in. One of the NASA engineers that we talked to suggested that once a robot makes a complete circle of the collection zone, and cannot find a way out, it can sometimes get stuck in a loop that it can't break out of. He suggested that

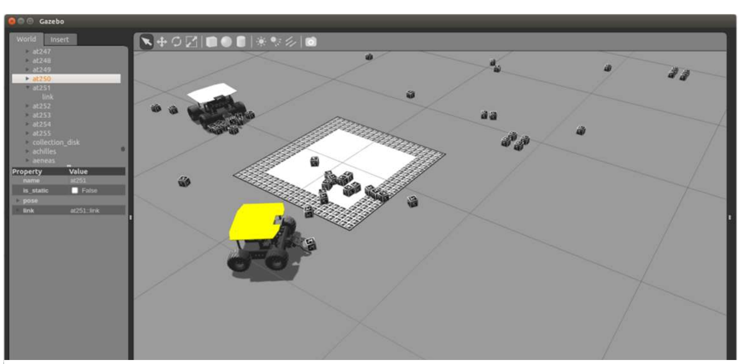

*Figure 2*

one of the ways that other teams handled that particular problem was to keep a record of the angle that was turned, and once a complete circle is attempted, have the robot drive forward slowly, hopefully clearing the center without knocking too many blocks out.

In the preparation for the competition and to test our code, we used a simulation program. Fig. 2 demonstrates that were able to collect a large number of cubes in the simulation mode.

One of the things we learned was that several behaviors observed in physical robots were not reflected in the simulation. Although we did not win the competition, it was an enormously valuable learning experience for everyone. As with most science, learning what does not work is just as valuable as learning what does work.

In summary, in the process of the research program, we encountered many challenges. In our activities, in addition to challenges related to our topic of research we have identified three main obstacles to our work: (a) software framework management i.e. software installation, software testing, hardware incompatibility, system stability, (b) task management i.e. accommodate multiple academic assignments with the research activities, (c) team management and coordination of activities supporting one another.

Generally, the research topics related to human detection in videos are highly motivating since these are visual real-world applications that need solutions. These areas, however, are full of challenges for beginners in AI since the differences between computer analysis of visual data and the natural process of human vision are not obvious. On one hand, tracking and understanding the behavior of a few persons in a limited area is effortless for humans whereas CV still faces difficulty with implementing this task. The problems start with detecting the presence of humans, counting how many are present based on detections, their locations, their tracks built out of the sequence of locations, and their identities which are derived from tracks. On the other hand, natural human vision is overwhelmed when tasked with detecting and tracking extremely high numbers of moving persons in a wide area. We see the opportunity for automatic crowd movement analysis to be important and probably invaluable in the future.

## V. Future Work

In terms of a software, we still need to extend our framework and include new modules to enable us or future students to quickly obtain meaningful results. After such modules are created, advanced analytics could be employed to understand dynamics in crowds, and determine certain patterns as they are taking place.

In terms of development of algorithms for CV controlling autonomous robot we need to experiment more with the physical robots. For that we will need a dedicated testing area, with access to wifi so that the robots can communicate with each other. Ideally, the area would have access to power and possibly be covered so that experiments can be conducted even in inclement weather.

## VI. Web Links

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| Group blog | https://surveillancegroup.wordpress.com/ |
| Catherine Spooner | https://myailifeblog.wordpress.com/ |
| Samantha Halam | https://technicallifesh.wordpress.com/ |
| Samuel Cooper | https://samuelcoopersite.wordpress.com/ |
| Lee Gibson | https://creuleegibson.wordpress.com/ |

## VII. Presentations and Publications

Automated Abnormal Behavior Detection in Crowds from Multi-Camera Videos. Poster Presentation. State of North Carolina Undergraduate Research & Creativity Symposium, North Carolina Central University, November 5, 2016

## Summer Internships

Members of our team were encouraged to apply for summer research internships leveraging their experience gained from this research. All three who applied were awarded internships.

Ms. Spooner was awarded an internship sponsored by Dept. of Energy VFP program.

Ms. Halam was awarded a cybersecurity internship at Norfolk State University.

Mr. Cooper was awarded a 2017 Research Experience for Undergraduates internship at the University of Miami.

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